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ADVANTAGES AND DISADVANTAGES OF RESERVOIR STORAGE.*

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AT the outset it must be admitted that the advantages of water storage are many and the disadvantages but few. In those days when the expression "stagnant water" carried with it all sorts of ill-defined fears, the opponents of storage were easy to find, and their enthusiastic statement that "abundance of light and air is essential to the proper conditioning of water for human consumption" received very general support. He who drank of the rapid stream was accounted greater in wisdom than he who selected a less aërated supply.

It is now almost trite to say that still water, rather than running water, purifies itself the better, and it equally lacks novelty to point out that the more rapidly a stream flows, the sooner is its load of pollution delivered to the thirsty consumer. In that connection, let it be said that a great deal more depends upon the number of hours required for stream flow than upon the distance in miles between the intake and the source of pollution, and a

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concise statement giving information as to time of flow should appear in a report covering the sanitary survey.

Stagnation has its disadvantages, of course. Increase in color naturally follows if water be permitted to long remain in contact with a muddy bottom loaded with soluble extractive matters. Not only is damage to the water's physical appearance a result of such contact, but the material passing into solution is likely to furnish abundant food for those minute forms of life which carry objectionable tastes and smells to many public waters.

To the layman's ear the word "stagnant" has a most unpleasant sound, intimately associated with the production of disease; and yet its origin is innocent enough, viz., "stagnum," a piece of standing water, not running in a current or stream.

Pools so overloaded with vegetable growth, both dead and alive, as to be unfit for human drinking are plenty and they are commonly stagnant, but the ill-favored word does not properly apply alone to those; it is just as applicable to a water of crystal clearness resting upon a bed of sand.

The condition of "standing water" just referred to,—namely, that of being overstocked with vegetable growths,—is practically the only one toward which objection can point when considering the *pros* and *cons* of reservoir storage.

The word "vegetable" is here to be taken in its broad sense, as it should include not only those growths which would be recognized by the public at large, but also those of the minute world as well, which latter constitute one branch of that lake life known as "plankton."

As an instance of excessive overgrowth, a small lake could be named which is so loaded with dense vegetation that decay gets ahead of new growth, and the use of its water is productive of temporary diarrhœa. It is a stained water, but its color is not to be considered as a measure of its objectionable qualities for table use, as many waters of much darker tint are of excellent quality for such purpose. Color and fitness for drinking bear no relation to each other.

It is true that colorless waters are now demanded by the people, and "meadow teas" are growing in disfavor, but that

change in public opinion is of recent date and is not based upon established hygienic grounds.

The deepening in color of the lower layers of a water stored upon an unclean bottom; the encouragement of growths of small organisms producing taste and smell by reason of an accumulation of extracted food suitable for their development; and a deficiency in dissolved oxygen in the bottom levels, constitute the sum of objections that can be raised to the impounding of water, and they are much more than balanced by the advantages that accrue from such storage.

The pollution from shore drainage that reaches a reservoir water is likely to be naturally much smaller in quantity than that received by a flowing stream; nevertheless, very serious pollution may occur in concentrated form, even when the efforts of the caretaker are the most earnest. Thus, the writer has seen numerous loads of stable manure spread upon the very steep banks of a small, cup-shaped distributing reservoir. The intention in this case was good, and much pride was taken in the fine lawns of the water-works park, but a better choice of fertilizer could have been made for such a location.

It is entirely possible to protect a reservoir, and to a great degree the water-shed also, if careful policing of the district be established. Country towns situated upon the banks of streams tributary to the reservoir are the sources of greatest danger, and an earnest effort should be made to remove all privies, manure heaps, farm yards, refuse dumps, and other sources of pollution from draining into the stream or any of its feeders. This is sometimes difficult to accomplish completely, but a high degree of thoroughness can be attained by suitable and tactful management.

Board of health rules are expected to cover care of public water-sheds, but rules and laws will not enforce themselves, and the city official is commonly at a distance and more interested in the distribution system than in that of collection. The most simple arrangement would seem to be to appoint a local physician in each town or village upon the water-shed as the sanitary inspector for that particular district, and to give him authority to employ an intelligent laborer as a sub-inspector to do the necessary work under his direction.

The writer has found this arrangement both efficient and cheap. In one noteworthy instance, besides caring for the sources of pollution noted above, the sub-inspector's duty included the daily patrol of a mile of railroad track which ran along the border of the reservoir. This question of possible danger from railroad pollution has but recently been recognized. Although it is always well worthy of consideration, there is no question but that it greatly varies in importance with change in topography, soil, or season. Rocky, steep slopes are easily washed by the rain, and frozen embankments naturally fall into the same classification, while flat road-beds and sandy soils offer better chances for polluting material to be disposed of by natural methods.

Whatever the character of the road-bed, it should be the sub-inspector's care to remove all night-soil dropped from passing trains, and he should exercise greater vigilance in winter than during summer.

The physician-inspector would be in a position to know of cases of disease, such as typhoid, in his district and, being so informed, could take proper precaution against contamination of the public water, which act on his part would be of vastly more practical value than a location of the trouble by some sanitary commission after an epidemic was well under way.

The greatest responsibility borne by the inspector, however, would be during periods when gangs of laborers were employed at construction work within the limits of the water-shed. Should the workmen be many and the time of their remaining be two weeks or more, nothing short of incineration of all camp waste and night-soil should be demanded, and the utmost care should be taken that sanitary instructions were carried out to the letter. A Woodruff pit, which can be constructed in a few hours, would be suitable for a temporary camp; while, if something more permanent were demanded, a well-constructed incinerating furnace should be built.

When meadow lands are flooded, the extraction of food for plankton growth must of necessity take place, and we are forced to choose between stripping the proposed bottom or else depending upon the employment of some means of killing or removing the organisms that are likely to develop.

As to what could be done to rid a water of the odors due to algal and other growths, the outlook was not very hopeful previous to the appearance of the "copper sulphate process" proposed by Moore and Kellernan in 1904 (Bulletins 64 and 76, U. S. Bureau of Plant Industry.

The method of applying this chemical is simple enough, and its use is very efficacious. Bought in bulk, it can be had at about five cents per pound, and its distribution is readily secured by filling it into perforated buckets, or even bags, and towing the same by row-boat or launch over the reservoir surface.

Decided objection was raised against such a process of "disinfecting" a public water supply, and the opposition was especially marked in England, but the use of it is still with us and is likely to stay, for the reason that the "dose" is minute and is only occasionally required, that it is reliable in results, and that experiment has shown that it is not followed by the evil consequences predicted.

It must be remembered that it is not added to the water continually, but is used only at stated and widely-separated intervals,—namely, at those times when the "crop" of minute organisms has become so well grown as to produce objectionable effect upon the water.

Perhaps one reason why the "coppering" of reservoirs has led to so much criticism is because of the dead fish that are to be seen after the chemical has been applied. When considering this effect upon fish life, one should bear in mind that the "dose" has of necessity to be applied uniformly over the surface of the water, and each acre of such surface presumably receives the same amount, irrespective of the depth of water that the acre covers. As a result, the shallow parts of the lake receive temporarily a greater quantity of the sulphate, per cubic foot of water, than do those which are deeper; again, the entire quantity of chemical intended for the whole body of the lake is delivered to a few inches of its surface layer; therefore, until diffusion has taken place, fish which chance to swim into such water receive a very concentrated dose and are likely to be affected by it. Distribution is complete by the time the water reaches the public mains, and, moreover, the minute dose used has been more or less completely disposed of through its action upon the organisms for whose destruction it has been employed.

In a paper before the Section on Hygiene of the Eighth International Congress of Applied Chemistry, 1912, Kellernan presented the following data:

QUANTITY OF COPPER SULPHATE REQUIRED TO KILL VARIOUS FORMS OF ODOR-PRODUCING ORGANISMS.

Copper Sulphate Required, Expressed as Parts, per Million Parts of Water.

Anabæna	.09	Kirchneriella	5. to 10.
Asterionella	.1	Leptomitus	.4
Beggiatoa	5.	Microspora	.4
Chara	.2 to 5.	Navicula	.07
Cladophora	1.	Oscillatoria	.1 to .4
Cladothrix	.2	Peridinium	2.
Clathrocystis	.1	Scenedesmus	5. to 10.
Cœlosphærium	.3	Spirogyra	.05 to .3
Conferva	.4 to 2.	Ulothrix	.2
Euglena	1.	Uroglena	.05
Fragilaria	.25	Volvox	.25
Hydrodictyon	.1	Zygnema	.7

He adds a list of twelve genera of algæ that in his experience are causing trouble in reservoirs and ponds:

NUMBER OF OBSERVED CASES.

Anabæna	27	Conferva	56
Asterionella	9	Crenothrix	13
Beggiatoa	20	Fragilaria	19
Chara	26	Navicula	21
Cladophora	17	Oscillatoria	49
Clathrocystis	23	Spirogyra	43

Jackson claims that blue-green algæ will die if the water be "coppered" one part to five million. His dose for Mellosira or Synedra is one to two million, and he claims that the former gives no odor of growth, but only that of decay. He finds that coppering runs out certain forms of organisms and substitutes others by a sort of selective action, but those thus substituted are not likely to be odor producers; and he further notes that, while "bottom" or decomposition odors are easily shaken out by aëration, "top" odors, viz., those of growth, have to be removed by filtering out the organism, or killing them by copper sulphate, or both. In his opinion, filtration of either type is effective for removal of odors of growth, but he believes that

aëration would be worse than useless for living plankton, for the reason that the agitation would tend to mechanically release the oil causing the taste, which oil is not very easily oxidized.

Naturally the cost of treatment with sulphate of copper will depend in part upon the amount of the chemical that is to be used, which in turn is determined by the kind of organism that it is intended to kill; but it may be said that a mixed growth of Mellosira and Asterionella was removed from the Troy reservoir at an expenditure of 14.9 cents per million parts of water treated, labor included. The dose was one part of copper sulplate to 3,500,000 parts of water by weight.

In the article by Kellernan above quoted there are figures given indicating the safe limit for treating water with copper sulphate when certain fish are to be protected.

Copper Sulphate, Expressed as Parts, per Million Parts of Water.

Black bass	2.1	Pickerel	.4
Carp	.3	Suckers	.3
Catfish	.4	Sunfish	1.2
Goldfish	.5	Trout	.14
Perch	.75		

It must be noted that these figures assume a thorough mixing of the sulphate solution with the whole body of water. They would not hold for the unequal distribution and resulting local concentrations already mentioned.

In some reservoirs which have been formed by the extensive flooding of swamp bottoms there may develop objectionable growths of *Crenothrix*, a general term denoting an aquatic plant which at times gives much trouble because of its tendency to develop in the street mains and clog the pipes. It is often discovered quite unexpectedly, being dislodged by the current attending hydrant flushing or by the draft caused by fire engines. Dead ends are spots likely to harbor it, and its long rusty filaments have been mistaken for horse manure.

There are three types of the growth, each possessing the peculiarity of precipitating from the water in which it grows its own particular metallic hydroxide. By far the commonest of the three is *Crenothrix Kuhniana*, which demands iron for its development and which deposits large amounts of iron hydroxide as the result of its growth. The iron required for growth

must be in solution, and the quantity demanded would seem to be about 0.3 part of Fe per million.

In order that the iron may be in solution, we naturally would expect the dissolved oxygen to be low and the quantity of reducing agents, such as organic materials, to be high, and those are the conditions that we find in practice to be favorable to the development of the plant.

It is likely to be encountered in waters from swampy, peaty sources where dissolved oxygen is scanty and where the necessary iron in solution may be had. Driven wells in such localities frequently furnish it. Darkness favors its growth, and its development in city water-mains is often excessive, resulting in a material reduction of the carrying capacity of the pipes. The writer has some doubt about the "manganese" variety of *Crenothrix* being as rare as some think it is, he having found large quantities of manganese in a heavy Wisconsin growth. Beythien and others[1] have, moreover, noted that the presence of manganese in water directly favors the growth of the ordinary form of *Crenothrix*.

Beyond the mechanical stopping of street-pipes, *Crenothrix* is exceedingly objectionable to the laundry interests of the community, for the reason that its rusty filaments cause "iron stains" to appear upon white linen.

Removal of the iron by oxidation and filtration is the best guard against troubles due to *Crenothrix*.

It must not be sweepingly assumed that all the "plankton" life is to be rated as uniformly objectionable; quite the contrary, as a reasonable degree of it acts as a distinct help in maintaining the safety of natural waters. Thus we find "bacteria eaters," such as many kinds of ciliated infusoria, rotifers, daphnia and the like, feeding upon minute germ life, and doing so to our great advantage.

To quote from a translation by Kuichling: "The question is, what becomes of the great quantities of offal and excreta, the many remnants of decaying plants, the refuse of communities, and the finely-divided factory wastes of every description, which find their way into our streams, even under normal conditions, if a large portion thereof is not consumed by the aquatic detritus-eaters and the omnivorous fauna before settling to the bottom?"

[1] *La Technologie Sanitaire*, September, 1914, p. 61.

With a view to avoid the troubles arising from the undue growth of taste- and odor-producing organisms, the stripping of reservoir sites and the removal of a portion of the upper soil has been advocated and carried into practice. This, of course, entails very great expense when the surface to be stripped is at all extensive, as in the instance of stripping the Nashua reservoir supplying Boston. At Columbus, Ohio, such work cost $159 per acre.

In their report upon the probable cost of stripping the surface soil from the Ashokan reservoir site, which is to hold the water supply for New York City, Messrs. Hazen and Fuller stated it would possibly reach the great figure of $5,000,000.

In view of the expense of such treatment for large reservoirs, the question is pertinent, "Does it pay?"

At Holyoke, Mass., the annual water report for 1908 says: "Great care had been taken in cleaning and stripping the reservoir by removing all vegetable and organic matter, thus lessening to a minimum the food supply for supporting living organisms in the water. The thorough cleaning of the reservoir has not been wholly successful, as an aquatic plant known as 'Chara' has grown and flourished in the reservoir all summer and imparted to the water a taste and odor that made it unfit for drinking or even for cooking purposes."

Mr. J. M. Diven ("American Water Works Association," 1908) has had interesting and contrasting experiences with both stripped and unstripped reservoirs:

"The Elmira reservoir was as thoroughly stripped as possible; great care was taken to keep out the first washing from the drainage area and the muddy flood waters. There was little or no marsh land on the drainage area, the catchment area being seemingly ideal. The reservoir was clean and clear; on the sides the slopes were abrupt, and there was very little shallow water.

"At Charleston, S. C., the drainage area was largely swamp, and there was much decayed vegetable matter on all of the area drained, the water being decidedly peaty. The reservoir covered a large surface, was shallow, and absolutely unstripped or even cleared. Much of the land flooded was composed of black muck or decayed vegetable matter.

"In the first case (Elmira) the conditions were at the first

satisfactory and the water good for several years. But trouble from algal growth came in time and has steadily grown worse, in spite of strenuous efforts to remedy the condition.

"The second case (Charleston) was troublesome and unsatisfactory from the first, but has somewhat improved and promises to continue to improve."

The writer's experience leads him to advocate the expenditure of comparatively little money in the preparation of sites for large storage reservoirs, for the reason that, although thorough stripping will likely give immunity from algal growths for some years, yet freedom from the occurrence of taste and odor in the stored water may not last for long. Sooner or later there will be carried into even the most carefully cleaned reservoir enough food material to sustain a plankton growth of a density governed by the local conditions. Broadly speaking, an "old bottom" is better than a new one, because it is likely to contain less plant food; but the rule has many exceptions.

Even natural lakes are frequently seen "in bloom,"—that is, loaded with minute life,—and they so remain for a period during which their waters are not acceptable for domestic use. The character of the tributaries must be considered as well as the nature of the bottom of a proposed reservoir, for it is manifestly loss of money to improve the latter if the former can quickly replace much of what has been taken away.

For the sake of general appearances, if for no other reason, trees, shrubs and bushes should be removed. Dead, standing timber and fallen logs are most unsightly and are very likely to produce complaint from the visiting public. In other words, the reservoir site should be cleared and grubbed, with, of course, entire removal of every vestige of human habitation; but beyond that it scarcely pays to go. The portion of the flooded land lying between high-water and low-water marks should receive especial attention, for the reason that during the periods of its exposure it is capable, if uncared for, of presenting an unpleasant appearance and provoking adverse criticism; with the further objection that heavy weed growth may develop if it be long uncovered, which growth will contribute toward the production of taste and smell when the water again covers it.

In an instance where it was proposed to restore a dam that had been out of repair for over fifty years the writer advocated

the cutting off of the standing dead timber at the existing water level before closing the breach, in order to insure a better looking sheet of water when the reservoir filled. This was for appearances only, as all extractive matter had been leached out of the old vegetation long before.

Aëration, filtration, and the judicious, occasional use of copper sulphate constitute the processes at our disposal for combating the annoyance arising from algal growths, and their use will give greater satisfaction than the expensive stripping of reservoir bottoms, a treatment which was so frequently advocated in the past.

Dr. A. C. Houston, of the London Metropolitan Water Board, has undertaken some very extended researches upon the question of water purification as a result of storage. He found that in stored Thames water the death of typhoid bacteria took place rapidly, although the rate varied with the temperature of the water. In cold water they lived longer than in warm, and 50° F. seemed to be a critical point above which their mortality rate was much increased.

In his 7th Research Report, Houston states that typhoid bacilli lived in stored raw Thames water for the following lengths of time: At 32° F., five weeks; at 41° F., four weeks; at 50° F., three weeks; at 64° F., two weeks.

Even these figures do not tell the entire story. Put in more detail they read:

	At start.	1 week.	2 weeks.	3 weeks.	4 weeks.	5 weeks.
32° F.	103,328	47,766	980	65	34	3
41° F.	103,328	14,894	26	6	3	—
50° F.	103,328	69	14	3	—	—
64° F.	103,328	39	3	—	—	—

He concludes: "It is difficult to escape the belief that thirty days' storage of river water is tantamount to sterilization, so far as the microbes associated with water-borne epidemic disease are concerned."

When experimenting with an artificially-infected water to determine the effect of storage upon the typhoid bacillus, Dr. Houston felt that any error so introduced was upon the side of safety, because he had previously shown the "cultivated" typhoid organism to have a greater longevity than the "natural"

Bacillus typhosus. In his report he dwells at length upon the advantages to be derived from "adequately storing the *raw* impure river waters." Even if there were no economic reason for storing a river water before rather than after filtration, yet it would be well to follow that course, aside from any question of algal growths, for the reason that sedimenting silt greatly assists in bacterial removal. Placing the word "raw" in italics was, therefore, a matter of good judgment.

Dr. Houston adds: "I am well satisfied that a well-stored, rapidly-filtered water is likely to be safer than an unstored, slowly-filtered water."

It is possible to go even further than this, for one can see how dangerous it might be to deliver, directly to the consumers, the water of a small and apparently pure mountain stream. The dejecta of a single typhoid carrier would render so small a volume of water highly infectious, if no storage intervened, and an outbreak might follow, such as occurred at Plymouth.

Although Dr. Houston is doubtless sound in his judgment that a great measure of safety will result from four weeks' reservoir storage of a polluted water, yet we must be assured that the period of storage is real and not simply apparent; or, in other words, we must know that *all* of the water really does remain in the reservoir for the specified length of time before it is used for public consumption.

Where the inlet and outlet of a reservoir are near together, as is not uncommonly the case, it makes but little difference what the capacity of the total storage may be; the water simply slips in and out again with practically as little stay as though the reservoir were a standpipe.

If the lake be long, narrow, and deep, and all of its water be obliged to traverse its entire length before being taken for supply, then the conditions would appear ideal for purification of the inflowing water before the outlet was reached, and yet even under those excellent conditions it is possible to have introduced unexpected and upsetting factors, as is instanced by the history of the typhoid epidemic at Auburn, N. Y.

Lake Owasco is one of the so-called "finger lakes" of western New York. Its length is about ten miles, breadth one mile; its watershed is about 190 square miles; and its depth is about 175 feet. A small stream enters its head, and Auburn,

a city of some 30,000 inhabitants, has an intake located at the north end or foot of the lake and forty feet below the surface. The temperature of the water at that point in May, 1913, I found to be 42° F.

The peculiar feature of the case which has special interest here is the possibility of polluting material of fecal character being transported from a village near the head of the lake, down the inlet stream, and then northward for the entire ten miles of the lake's length to the Auburn intake situated near the lake outlet.

We have all faithfully held to the dictum that "sedimentation and time" are the great purifying agencies upon which to rely for the natural improvement of a once polluted water; and it takes a good deal of evidence to persuade us that sewage of a small village could make the trip down such a lake in a length of time and in such a manner as to dangerously affect the water of the lower end. Experimental data, however, have been secured showing that such a result can actually take place. Investigation showed the following facts: The village sewage was, of course, small in volume, but during the winter months it was deposited at several points upon the banks of the inlet stream and there it collected in a more or less frozen condition until the occurrence of the spring thaw, at which time there was opportunity for much accumulated fecal material to be washed into the lake in a state of suspension. There was also a chance of its being actually ferried upon cakes of ice, for the reason that certain privies were located upon bridges and fecal matter was dropped upon the very centre of the ice-covered stream.

As stated, the shape of the lake is long and narrow and its axis lies north and south. It must be further noted that the prevailing wind is from the south, with a tendency to blow the surface water directly toward the city intake at the north end.

By means of triangulation and the use of floats constructed so as to be moved by water currents existing at the different depths of from five to twenty feet, it was ascertained that the upper strata of water moved northward with the wind, as would have been expected. The rate of this movement being ascertained, it was found that with relatively light winds the movement of the water down to a depth of five feet amounted to about three per cent. of the wind movement, while at lower

depths this water movement diminished to as low as three-quarters of one per cent. of the wind movement. Thus, to quote from the figures of Mr. Ackerman, who made these tests, with a wind movement of six miles per hour the percentage which the water movement was of the wind movement was as follows: At 5 feet depth, 3.2 per cent.; at 10 feet depth, 1.74 per cent.; at 15 feet depth, 0.87 per cent.; at 20 feet depth, 0.75 per cent.

With a higher wind velocity the water also travelled with greater velocity, but its movement was then not so large a percentage of the wind movement. Thus, with a wind blowing 17 miles an hour the water movement at a depth of five feet amounted to but one and a quarter per cent. of that of the wind. From these data it was easy to calculate that pollution entering the head of the lake could make the trip to the foot of the lake in three days or less.

Knowing, as we do, from Dr. Houston's experiments, that cold water below 50° F. will favor the longevity of the typhoid fever bacillus, it is easy to see how entirely possible it would be for living germs to reach the intake in dangerous condition.

It will be noted how striking is the resemblance which some features of this case bear to the classic instance of the outbreak of typhoid fever at Plymouth, Pa., where the whole trouble came from the dejecta of a single individual being thrown out upon a hillside where it froze and accumulated for weeks and finally, upon the coming of the thaw of spring, was washed into a stream tributary to the city reservoir. This sudden washing of accumulated fecal material furnished in both of these instances a volume of pollution out of all proportion to the amount which would be daily derived from the contributing population during ordinary times of fair weather, and as a result it overtaxed and broke down nature's ordinary means of purification and protection.

There is no question but that this particular case, showing, as it does, the dangers that may arise from such winter accumulation, and showing further the possibility, under favorable conditions, of the transportation of such material over considerable distances in a lake, will cause many of us to materially amend our notions about the dependence to be placed upon lake and reservoir storage as a means of protection against the evils

following water pollution. We should not trust to simple storage without a thorough knowledge of just how it is being accomplished. The writer has in mind an instance of a large lake some five miles in length which has a stream entering within one mile of a city intake, and, because of the entering water having a low specific gravity, there is a possibility of its flowing over the surface of the lake toward the intake whenever the wind is in the right direction. The great length of that lake is, under such circumstances, of small value for purification purposes.

All of this certainly goes to show that we should be cautious about banking too strongly upon the efficiency of reservoir purification under all circumstances, and it demonstrates the necessity of our being well acquainted with the conditions surrounding each individual case before venturing an opinion on the matter.

It should be noted here that, in judging of the bacterial efficiency of lake or reservoir storage, the interpretation of the results of an examination may be obscured by an increase in the total count of bacteria reported due to the disturbing influence of the spring or autumn "turnover."

In conclusion, permit a word to be added concerning the value of storage as a protection against spreading disease through the use of an "emergency" water supply. The underwriters very properly insist upon a sufficient fire service, which shall be available in the event of a temporary breakdown of the regular distribution system. It too often happens that upon such occasions a very inferior water is supplied by the "emergency intake," and as a result of its use there follows an outbreak of typhoid fever. Commonly, some old intake is allowed to remain in place for "emergency service," when pollution of the former supply has so grown in intensity as to force the authorities to seek a new source for public water.

Further fouling of this old supply goes on progressively as population increases, until after some years the water becomes practically dilute sewage. Suddenly some accident to the regular water system induces the authorities to open the old gates, and the result may be imagined.

Such has been the history of typhoid epidemics in a number of cities.

Storage for a sufficient length of time, supplemented, if necessary, by an appropriate dose of bleaching powder, will render even a poor water acceptable for emergency uses, and the reservoir capacity for such storage need not be large.

(There followed lantern slides giving photographs of various forms of microscopic animal and vegetable life, especially those that produce taste or smell in water. Views were also shown of reservoirs before and after stripping; floats used to measure lake currents, and methods for protecting a water-shed against pollution.)

Radio-active Thermo-mineral Waters. G. MASSOL. (*Comptes Rendus,* clv, 373.)—The springs at Usson consist of three groups: (1) three springs at Source Condamy; (2) one spring at Source des Plaies; and (3) two springs at Source Soumain. They all contain about the same quantity of sulphur. The waters from the first two groups evolve on boiling about 16 to 20 c.c. per litre of gas which contains about 1 per cent. of carbon dioxide and hydrogen sulphide, the residue being nitrogen and inert gases. The gases are radio-active, and the calculated activity of the waters is the same for both groups.

Sweden's Hydro-electric Development in 1911. ANON. (*Sci. Amer.,* cvii, 9, 175.)—The hydraulic plants erected in Sweden in 1911 amount to nearly 40,000 horsepower, and if the extensions to existing plants are included, the total will reach 67,667 horsepower, as against 62,385 for the preceding year. These figures refer only to electric power plants installed by private companies. The height of the fall used here is generally made 80 feet, but varies up to 240 feet.

The Electric Furnace and Ferro-silicon. ANON. (*Sci. Amer.,* cvii, 9, 175.)—The electric furnace process is very advantageous for the production of compounds of iron and silicon or ferro-silicon; and even pure silicon can be produced. By the usual blast-furnace methods the best that can be obtained is a product containing a maximum of 20 per cent. silicon, but much richer compounds are obtained by the electric process. Moreover, the impurities, such as calcium, manganese, carbon, etc., are much lower than by the old process. Ferro-silicon containing less than 30 per cent. or over 65 per cent. of silicon is stable, but products between 30 and 65 per cent. are easily decomposed. From the chemical standpoint it is admitted that there are three iron silicides, and perhaps two others. The present process is now being operated in Europe and is covered by patents; the electric furnace somewhat resembles a calcium carbide furnace, but to obtain good results a large-sized furnace is essential. They should also be near to the supply of raw material, and should have good transportation facilities for the finished products.

LIGHT SIGNALS.*

A DISCUSSION OF THE OPTICS, SOURCES OF ILLUMINATION, AND MOST EFFICIENT DISTRIBUTION OF LIGHT FOR RAILWAY SIGNALS GIVING DAY AND NIGHT INDICATIONS.

BY

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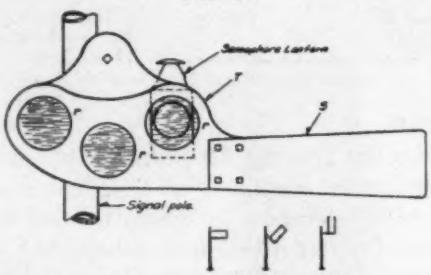
CHAPTER I.

ELEMENTS OF SIGNALLING.

Introductory.

FOR the benefit of those not familiar with modern practice, the author believes it best to outline the purpose of railway signals.

FIG. 1.



To permit the safe handling of traffic, it is necessary to provide a minimum space interval between trains running in the same direction, and, in addition to this, on single-track lines, to control meeting points for trains running in opposite directions. Where tracks cross at grade it is necessary not only to give one train the right to proceed but at the same time provide a means of stopping certain other trains which might attempt to use the crossing at the same time. Starting with a flag and a lantern, many forms of signals have been developed, all being designed to convey orders to the runner, to "signal" him whether he is to stop his train or proceed with safety. Within the limits of this paper there is no space for discussion of the numerous signals which have been used; it is enough to state that present-

* Communicated by the author.

day practice favors the "semaphore" signal, which in its latest "upper quadrant" type is shown in Fig. 1. The semaphore arm is composed of a wooden or metal blade *S* attached to a heavy metal frame *T* known as the "spectacle," which carries three colored glass "roundels," *r, r, r;* behind these roundels there is a lantern, and at night the color of the light is thus determined by the blade's position. The different aspects presented by this semaphore and the "indications" or orders which these aspects convey to the engineer are given in Table I, which also shows the corresponding colors commonly used for night indications. All parts are properly counterweighted to insure the semaphore arm returning by gravity to the "stop" position.

TABLE I.

Aspect Fig. 1.	Position of blade.	Color of light at night.	Indication.
A.....	0°	Red	Stop.
B.....	45°	Yellow	Proceed with caution, expecting to stop at next signal.
C.....	90°	Green	Proceed.

The Block System.

In controlling the spacing of trains in his territory, a dispatcher must maintain telephone or telegraph connection with numerous agents or operators to whom he can transmit orders for stopping trains. His division is subdivided into a number of "blocks," this appellation being given to the distance, perhaps two, perhaps ten miles, between his agents at the block stations. Any agent when so ordered by his chief or for sufficient reasons of his own may display a stop signal and detain a train for orders or until he gives the engineer and conductor permission to proceed.

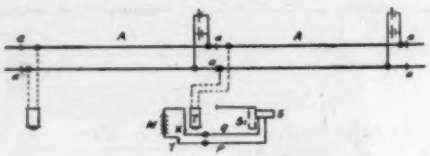
The usual practice in "telegraph block" signalling is to permit but one train at a time to occupy a block, though two or more freight trains may under certain conditions be allowed to occupy the same block under restrictions somewhat limiting speed. As the number of trains increases, the length of the block must be shortened, necessitating additional stations and operators. Both the expense of maintenance and the annoyance of train delays will then increase rapidly. As a result, the "automatic block" system is desirable and is now in extensive use, either as a supplement to the telegraph block or superseding it altogether. While this

does not relieve the dispatcher of his duties in getting trains over the division, it enormously increases the capacity of the line on account of the greatly diminished space interval between trains, and at the same time, as may be seen from the ensuing description, it adds greatly to safety by substituting for the human element an automatic train spacing. Experience has shown the automatic block system to be very dependable, millions of correct signal operations being obtained for every dangerous failure.

Reduced to its elements, the automatic block system consists of a series of track circuits, each of which controls an automatic signal, these circuits being so constituted that when the rails of any track circuit are short-circuited by the wheels and axles of a train the signal which this track governs is allowed to assume the stop position.

The automatic signal is usually a semaphore arm (similar to Fig. 1) whose position is controlled electrically by a battery *M*,

FIG. 2.



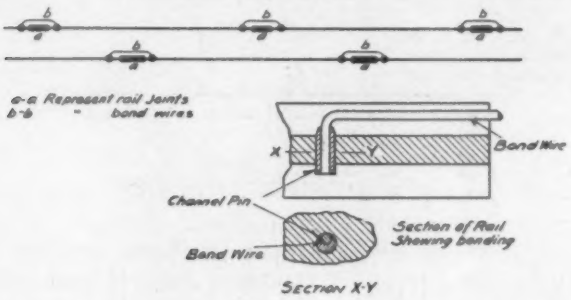
an electric motor, and a system of gears and holding magnets. Referring to Fig. 2, *p* and *q* represent the two wires connecting battery *M* with the electric mechanism operating the semaphore *S*; opening the circuit *pq* de-energizes the magnets holding *S* in the clear position and allows the semaphore to drop back by its own weight to the stop position S_1. The position of *S* may thus be controlled by a relay *T*, the magnets of which when energized cause contacts *xy* to close, thus completing the circuit between battery *M* and signal *S*.

The track to be signalled is divided into a number of short "blocks" *A*, usually about 4000 feet long, by insulated rail joints *a*, and each block *A* thus constitutes a local circuit. At one end of this block a few cells of battery are connected to the track, and the current from this battery passes through the rails to the 4-ohm relay *T* at the opposite end of the block and energizes the magnets of this relay so as to close contacts *xy*. To maintain electric continuity, the rails are "bonded" as illustrated in Fig. 3.

When a train enters section *A*, the wheels and axles constitute a very low resistance "shunt," and relay *T* is de-energized, allowing the signal to return to the stop position, where it will remain so long as the train occupies the block. As the entire division is composed of a succession of block sections *A*, a train is always protected by a stop signal behind it, which forbids a following train entering the occupied block.

Trains are frequently run at such speeds, on such descending grades, and with such brake equipment that it is impossible to stop under 3500 feet; the track alignment or the location of signals is very often such that an unobstructed 3500-foot view cannot be had, and, even when such a range is possible, weather conditions may be such that the signal indication cannot be read at that distance. It is, therefore, deemed necessary to arrange the auto-

FIG. 3.



matic signal circuits so that the presence of a train two blocks in advance may be indicated as a warning to following trains. Many schemes are in use to secure this protection, but space permits only the description of the "three-position" automatic block giving the "proceed," "caution," and "stop" aspects illustrated in Fig. 1.

To understand the protection afforded by this system, refer to Fig. 4. *A, B, C,* etc., represent the adjacent sections of a continuous automatic block system; *a, b, c,* etc., are the signals governed by these sections; the position of every signal is governed, first, by the track relay of its section (see Fig. 2), and, second, by the position of the signal in advance; thus while there is no train in block *E* the signal *e* is standing at caution, indicating that the block *D* is occupied and warning the engineer

to reduce speed. The most dangerous condition occurs when a train *X* has stopped immediately after entering block *B;* but the reader will note that the following train *Y* is warned by signal *c* in the caution position that he must be prepared to stop at *b*. The necessity for such protection has been emphasized in practice. For example, in the situation shown in Fig. 5, where no caution signal has been provided and train *O* has stopped just inside block *M*, a following train *P* would get a proceed signal *n*, and would not slacken speed. The severity of a collision would be aggravated if stop signal *m* were visible only a short distance.

Range.

Analysis of the signalling system in Fig. 4 will show the reader that the range of a signal—the distance from which an

FIG. 4.

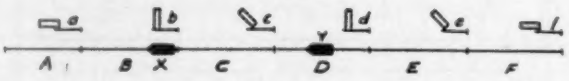
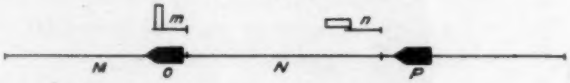


FIG. 5.



indication can be clearly recognized under most unfavorable conditions—together with the maximum distance required to brake trains to a standstill, jointly influence the speed at which trains can be safely operated. Before fixing the signal range, which is to some extent variable and determined by the design of the signal, due consideration must be given to the factors of speed and braking, which cannot be varied without great inconvenience and expense. Speed is limited by the topography of the country which a railroad traverses and by the maintenance and quality of roadway and equipment. The condition of the air brakes is by far the most important factor influencing speed, but, as the effect of brakes is itself varied by grades, it is necessary to present a series of curves for different grades if any accurate idea of brake performance is to be obtained.

It is with some hesitation that the author ventures a discussion of braking distances, realizing that many factors must be taken into account, and that, therefore, any comprehensive or

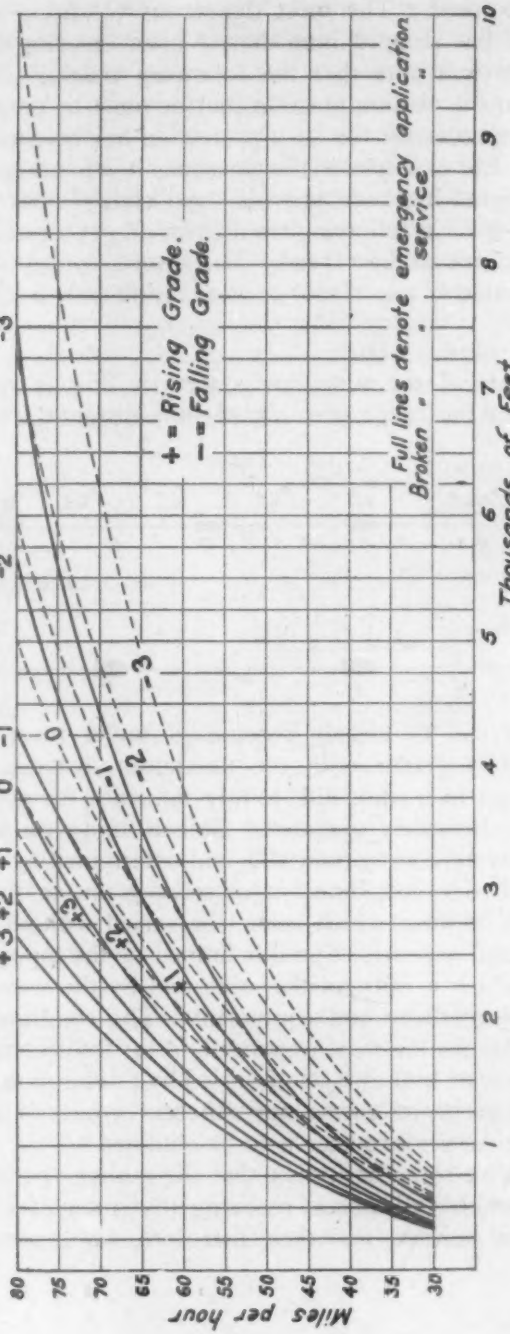

Miles per hour
80
75
70
65
60
55
50
45
40
35
30
Per cent rising and falling grade.
+3 +2 +1 0 -1 -2 -3
+ = Rising Grade.
- = Falling Grade.
Full lines denote emergency application
Broken " " service "
1 2 3 4 5 6 7 8 9 10
Thousands of Feet
Distance required to brake trains.

FIG. 6.

universal statements are impossible. Moreover, as improvements in brake design are keeping pace with those in other progressive branches of engineering, all present data may soon become obsolete. The curves, Fig. 6, are submitted merely as an indication of what will be obtained under the assumed set of conditions which are believed to be typical of brake equipment and maintenance commonly found to exist on passenger trains. We may consider these curves typical of the distances required to make " full service " and " emergency " stops with good average brakes of the ordinary " high-speed " type and 110 pounds brake-pipe pressure. Engines running light may sometimes exceed these braking distances, as they are not braked up to their full wheel load.

Empty freight cars can be braked readily enough, but a train of loaded cars is harder to handle, as it is not yet customary to increase the brake-shoe pressure on loaded cars over that on empties; as a result, a loaded freight train is usually only braked to about 20 per cent. of its wheel load. Unless the speed is carefully regulated, especially on falling grades, such a train will require a very great distance to brake to a standstill. One cannot, therefore, predict any definite maximum braking distance for freight trains. It is safe to assume, however, that common practice limits the speed and load of freight trains to a point where they can be stopped in 3000 to 4000 feet. Where conditions exist where it is impracticable or undesirable to keep within this limit, it is necessary to provide longer blocks or else to use some overlap protection as illustrated in Fig. 63.

The intersections of the vertical lines with the curves of Fig. 6 indicate the speed in miles per hour permissible if a train is to be stopped by signals whose ranges are denoted by these vertical lines. Unless means be provided to give advance warning of its position, average conditions will seldom allow a signal to be recognized at sufficient distance to insure bringing a fast train to a stop without overruning the block, and the caution indication as described in Fig. 4 was accordingly designed to prevent trains coming upon stop signals without advance warning to reduce speed. Every precaution is taken to prevent a train from a siding taking the main line after an approaching main line train has passed the second signal in the rear. It may be said that on a well-signalled road only deliberate violation of the book of rules by a train crew, or an accident to rolling stock or structure,

can cause a stop signal to be presented in the face of a train authorized by the last signal to "proceed at full speed." Therefore, arguments for long-range indications as a means to prevent overrunning a "stop" signal, though certainly worthy of attention, concern a theoretical factor of safety and cannot be said to have a direct bearing on the normal operation of trains. There remains, however, this very practical consideration: trains are frequently passing "caution" signals directing the engineer to bring his train under control so that he can stop if necessary at the next signal. It is not always possible or customary to locate caution signals as far behind home signals as would be necessary to insure all trains being stopped without overrunning the home signal if the runner does not apply brakes before passing the caution signal. For this reason, it is an advantage to have a distant signal which can be seen 1500 to 2000 feet, as the long range of this signal will have a similar effect to a signal of shorter range set farther back of the home signal. Reference to Fig. 6 will show that a signal having 2000 feet range can be seen far enough to brake an express train from 54 miles an hour to a standstill on level track without overrunning the block if the runner makes a "full service" application when he first sees the signal. It is obvious that with such signals both the safety and convenience of train operation is increased, especially where caution signals are located but a short distance from the home signals which govern them. Moreover, the increased range results in the runner being able to avoid excessive braking and still obey signals.

Those interested in a more complete description of block signalling are referred to Mr. J. B. Latimer's book, "Railway Signalling in Theory and Practice" (Mackenzie-Klink Publishing Company, Chicago).

CHAPTER II.

THE LIGHT SIGNAL.

Having considered the elements of signalling, we can now intelligently study the factors involved in the design of light signals.

The ordinary semaphore lantern used for night indication is, strictly speaking, a light signal; it projects a beam of approximately 60 candle-power, which, while sufficient for a range of one

to three miles at night depending upon atmospheric conditions, is not designed for daylight indications. Throughout this article we shall use the term *light signal* in its customary significance as referring to signals projecting sufficient candle-power to afford satisfactory indications in daylight, as well as night.

Small light signals having a daylight range of 100 feet or more have been used for years on trolley roads, principally to hold cars on passing sidings; they have also been used in tunnels and at stations, and locations where the subdued light is favorable for displaying a signal of low candle-power. The first extensive application of light signals to railroad service was the installation on the Pennsylvania Tunnel and Terminal Company in 1910. These signals were designed by the Union Switch & Signal Company and were of the form shown in Fig. 7, the indications being given by one 40 watt and one 20 wall Tungsten lamp behind each lens, the lenses being colored as indicated in Fig. 7. In these signals it was not necessary to secure a range of more than 500 feet, consequently small lenses with large lamps behind them so arranged as to give considerable spread to the projected light were found satisfactory.

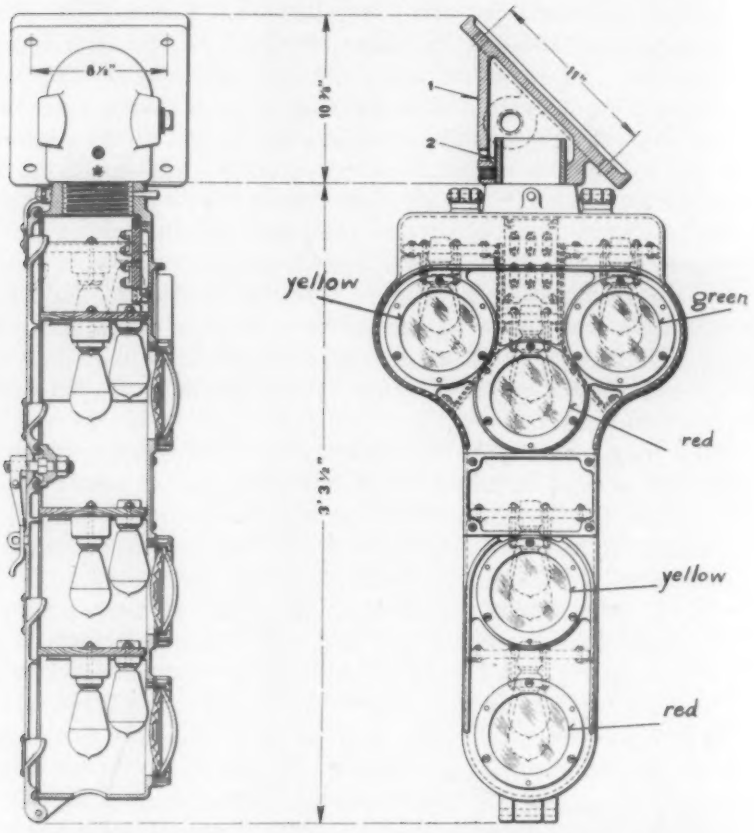
In these initial light signal installations color only was employed to give an indication and this practice has been maintained throughout the developments of the last four years. During this time light signals have been employed to some extent, both for interlocking and automatic block signalling on interurban lines.

It has been found advisable, however, to constantly increase the range of light signals, and as a result the design has been altered from Fig. 7 to Fig. 8, which illustrates a construction now in service. The colored lenses *G, Y, R* are placed close together to economize space, and in order to make the lights clearly visible in sunshine at ranges of 1000 feet or more it has proved necessary to surround the lenses with a large background *A* and enclose them in a hood *B*, both *A* and *B* being preferably painted black. With this arrangement uncolored glass would project a candle-power of about 400, and the color densities used in the signal are such that it may be seen 1000 feet or more under reasonable conditions.

As electricity was usually cheap and convenient in these light signal installations, it has been customary to burn behind the lenses (Figs. 7 and 8) 25-watt or 40-watt lamps, of which Fig.

17 is an example. This arrangement is not economical and the increasing need for longer ranges at low power consumption has determined a marked increase in the efficiency of light signals which we will further describe under the headings of "Lamps"

FIG. 7.



Sectional side view. Front view.

Suspended five-light electric light automatic signal. For daylight indications.

and "Lenses." The reader may at this point be interested in noting the curves in Fig. 24, which illustrate how, by reducing the size of the filament, we have been able to increase the intensity of the projected beam from 400 to 6000 or 7000 candlepower. This efficiency is further augmented by selecting the

proper lenses, this being discussed on another page of this paper. To anticipate, we may here state that the candle-power of a light signal has been made fifteen or twenty times greater at the same

FIG. 8.

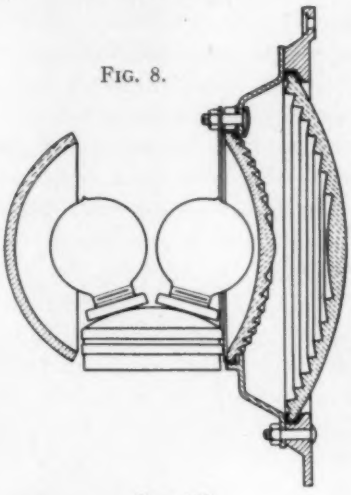


FIG. 8A.

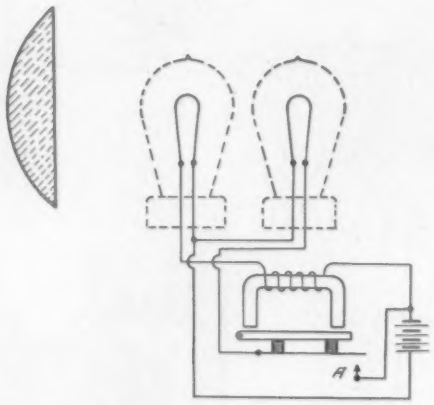
FIG. 8B.

time that an actual reduction in power consumption has been secured, all this being accomplished by employing lamps and lenses of the highest possible efficiency.

In the construction shown in Fig. 8, two lamps have been

mounted behind each lens, the front lamp being in focus and projecting about 90 per cent. of the total beam candle-power, the rear lamp being burned as a safeguard in case the front lamp is burned out. A combination lens is used having an especially wide angle and a very short focus and thus collecting a large percentage of total spherical candle-power of the front lamp. On account of the short focal length of this combination lens, the rear lamp is far out of focus, and a reflector has therefore been provided to superimpose the image of the rear filament upon the front filament, as otherwise the lens would be very slightly illuminated by the rear lamp. To decrease power consumption and increase the life of lamps, it is possible to utilize the well-known device of a

FIG. 9.



relay (Fig. 9) connected in series with the front lamp. In this case the rear lamp is held in reserve and lit only when the front lamp burns out, closing the back contact of the relay and completing the circuit of the rear lamp shown.

Light signals are being installed in increasing numbers, at present chiefly on electrified roads and interurban lines. These signals are safe and easily maintained; they occupy small space, and they may be readily recognized in congested territory or where the right of way is obstructed. Their current consumption is too high to permit economical operation from batteries, except where very low candle-power is required or where signals are displayed only for short intervals of time. Where power is available, either alternating or direct current, light signals may be

operated cheaply, require minimum attention, and provide a very high factor of safety. Suitable power is now becoming abundant, for in recent years alternating current has been supplanting batteries for the operation of automatic block signals. Its use makes possible the elimination of failures due to foreign direct current in the track circuit and also effects increased economy in maintenance.

It would require too much space to discuss the advantages of alternating current signalling; if interested, the reader is referred to a series of articles on this subject by Mr. Harold McCready, appearing in the *Signal Engineer* between May, 1913, and this date, and to the historical reviews of alternating current signalling published in the annual proceedings of the Railway Signal Association for the past four years.

If the light signal is to be adapted to the needs of modern signalling it must be sufficiently prominent to control fast trains, and at the same time its current consumption must be reduced to a minimum, for, even though power be reasonably cheap, the current taken by the light signal lamps, 24 hours a day, will represent a large percentage of the total operating cost of a signal system employing light signals. It is also desirable to keep down the first cost of a signal installation by reducing the power taken by each signal unit, as this frequently permits economy of copper in that very expensive element, the power transmission line.

The design of a light signal, therefore, aims at securing the greatest range with the least lamp wattage, and the remainder of this paper analyzes those conditions and theories upon which correct design must be based.

CHAPTER III.

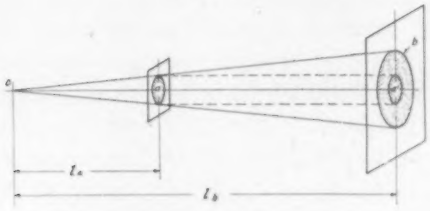
THE INCANDESCENT LAMP AND ITS INFLUENCE ON LIGHT SIGNAL DESIGN.

If increase in the efficiency of light signals is to be secured, there are two factors which assume primary importance. The projector, as we may call the lens or reflector, must be designed to utilize the greatest possible percentage of the lamp's total spherical candle-power, and to distribute this light in the most efficient and satisfactory manner. The source of light must be of such size and so located as to permit the greatest possible pro-

portion of its total spherical candle-power to be projected in useful light. The source of light—in our case the lamp filament—will be considered first as having the most marked influence on efficiency, but, before anything further is said, we must understand two principles underlying the design of a signal or reflector.

Neglecting several factors which influence the range of a signal light, the "visibility" of a light—the effect which it produces on the observer's eye—is proportional to the candle-foot illumination at the observer's station. One candle-foot is an illumination equal to that thrown by a one candle-power light on a surface one foot away. Obviously, if you take a naked light, the candle-foot illumination at any point is equal to the candle-power of the light divided by the square of the distance in feet between that point and the light, for, referring to Fig. 10, the

FIG. 10.



same amount of light that falls on a surface a distant l_a from the source of illumination O will be distributed over a larger surface b if the distance is increased to l_b, and $\frac{b}{a} = \frac{l_b^2}{l_a^2}$; therefore the amount of light falling on a surface $a' = a$, distant l_b from O, will be $\frac{a'}{b}$ or $\frac{l_a^2}{l_b^2}$ of the light received by surface a. It will thus be seen that the illumination afforded by a light diminishes very rapidly as the distance increases.

Figs. 11 and 12 show respectively a lens and a parabolic reflector, both concentrating that portion of the total spherical candle-power included in the shaded cones bounded by the lines AoB and $A'oB'$. The effect of this concentration is to increase the *useful* candle-power by avoiding dispersion of light where it is not needed. It might be thought that by combining a perfect projector with a point source of light, and so focusing it as to project a parallel "tube" of light, this law of inverse squares

would no longer hold and the candle-foot illumination would be the same at all distances; as a matter of fact, no commercial lens or reflector can be built without giving some spread, and it is likewise impossible to secure a point source of light, consequently the light from any lens or reflector will always be projected as a cone having greater or less spread, depending upon the construction and also upon the area of the source of light, and the

FIG. 11.

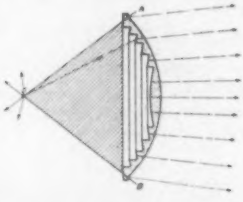
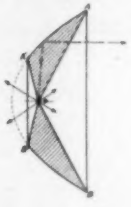
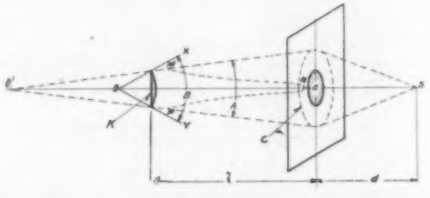


FIG. 12.



law of inverse squares may be said to apply universally. The amount of spread has no effect on the law of inverse squares, but it changes the candle-power decidedly; referring to Fig. 13, lens K collects all the light from source O included in the cone XOY having angle B, and projects this light, which is $\frac{1-\cos\frac{B}{2}}{2}$ of the total spherical candle-power in a cone of much smaller angle A.

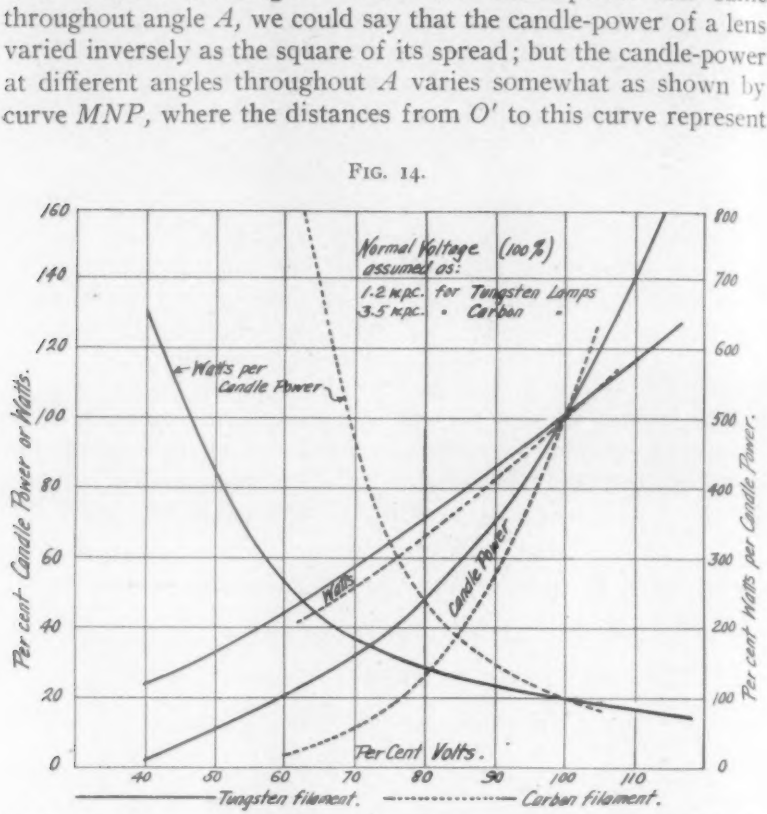
FIG. 13.



Now the candle-power of the projected beam A is photometered by moving a light of known candle-power S into such a position that the illumination thrown by this standard lamp on a small photometer screen having area a is equal to the illumination received from lens K. The candle-power of K is then determined simply by the law of inverse squares, viz., $Kcp = \frac{l^2}{d^2} Scp.$ Obviously, the greater the angle A the greater the area C over

which the light from K is spread and the smaller the percentage of the total light XOY received by the photometer screen a, whose area remains unchanged. Were the candle-power the same throughout angle A, we could say that the candle-power of a lens varied inversely as the square of its spread; but the candle-power at different angles throughout A varies somewhat as shown by curve MNP, where the distances from O' to this curve represent

FIG. 14.



Variation in candle-power, watts and watts per candle-power caused by variation in voltage at which lamp is burned.

candle-power. Thus we cannot make any general statement, except that the candle-power of a lens or reflector decreases rapidly with the spread of the projected rays; the exact decrease can only be given for specific cases.

Lamps.

Only tungsten lamps will be considered as a source of illumination, as they are more economical and satisfactory than carbon lamps; a carbon lamp of the small candle-power desired will

require 3 to 4 watts per candle-power, while tungsten lamps of the same size will require only 1.25 to 1.5 watts per candle-power. Furthermore, the light from the tungsten filament, even when burned under voltage, conforms more nearly to that of sunlight than does the carbon filament lamp, the shorter wave-lengths of the tungsten lamp between the *D* and *H* lines of the spectrum being more powerful (see Fig. 69); moreover, the reduction in its candle-power, due to lowered voltage, is less than that of the carbon lamp, as can be seen by inspection of the typical voltage = candle-power curves for tungsten and carbon filaments shown on Fig. 14.

FIG. 15.

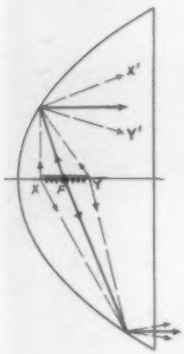


FIG. 16A.

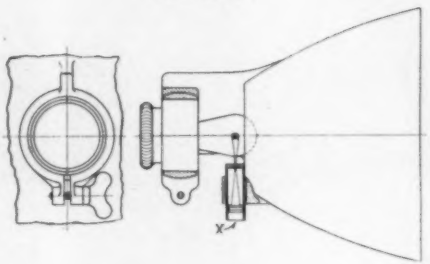


FIG. 16B.

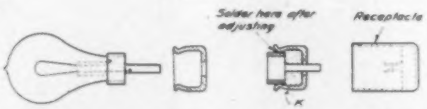


Fig. 16A shows a sight for locating a lamp filament correctly at focus of signal. Fig. 16B shows an adjustable base which can be aligned correctly with lamp filament and thus correct for variations in the manufacture of lamps.

If efficiency be measured by the watts energy required to project a certain candle-power from a lens or reflector, it is obvious that the greatest efficiency can be secured by concentrating the light in the smallest possible space as close as possible to the focus of the lens or reflector. Referring to Fig. 15, you will note that all that portion of the filament *xy* lying outside the focus *F* of the parabola projects diverging rays, and that only that portion of the filament located at *F* is really efficient in projecting candle-power; the same is true of a lens. For manufacturing reasons it is not practicable to concentrate all the light at a point, and it is not desirable to reduce the spread of the

projected beam too much. As the source of illumination approaches a point, a very small shifting of the lamp globe will throw the incandescent filament out of the focus; in the manufacture of incandescent lamps and lamp parts $^1/_{16}$ inch to $^1/_8$ inch variation in the location of the filament is to be expected. If a very small filament is used it is advisable to provide an adjustable lamp socket *A*, Fig. 16, so that when renewing a lamp the

FIG. 17.

110-volt, 25-watt.

FIG. 18.

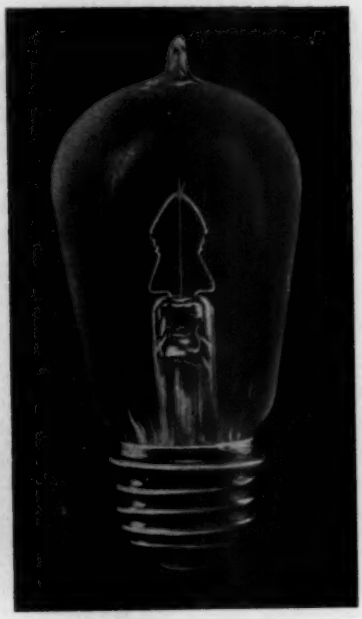
110-volt, 25-watt.

maintainer can readjust the socket to bring the filament right at the focus, using a finder *X* to determine the correct location of filament; or the base *K* of every lamp may be located in exactly the correct relation to the filament, as shown in *B*, Fig. 16, so that all lamps will be interchangeable without any readjustment of the signal. Unless this is done, the size of the filament must be increased to compensate for variations in its location. We can secure a certain candle-power and spread of light with a 20-watt concentrated filament accurately located at the focus of the signal

FIG. 19.

55-volt, 15-watt.

FIG. 20.



12-volt, 10-watt.

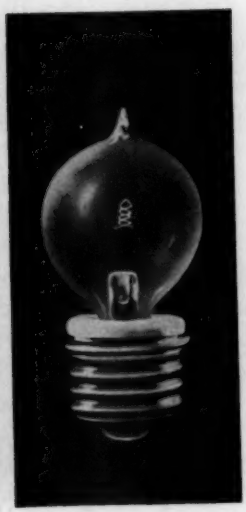
FIG. 21.

12-volt, 10-watt.

FIG. 22.

6-volt, 5-watt.

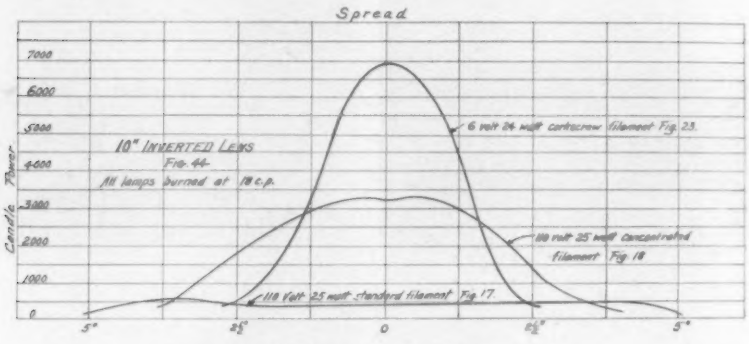
FIG. 23.



6-volt, 15-watt.

lens or reflector. If we attempt to use lamps having a $^1/_{16}$ inch variation in position of filament and expect to renew these lamps without any adjustment, we must increase the lamp watts to about 50 to compensate for variations and prevent the spread or the candle-power of the signal from being seriously affected by a change of lamps. Similarly, $^1/_8$ inch variation in the location of lamp filament would require an increase to 110 watts to compensate. Undoubtedly the best results can be secured, and at the least expense, by accurately locating the filament with respect to the base, as otherwise the maintainer will have to re-align the lamp receptacle every time he renews a lamp.

FIG. 24.



Comparison of different lamps behind the same lens.

Within the past year manufacturers have done much to develop a concentrated filament lamp by winding the tungsten filament in a fine helical coil and looping this coil over the filament supports. As an example of the extent to which the light has been concentrated, the author submits photographs of seven tungsten lamps (Figs. 17 to 23 inclusive); Fig. 23 is a "corkscrew" filament automobile headlight lamp, which has been in use for several years in parabolic electric headlights. In this connection it is interesting to note the comparative distribution of light from the inverted lens illustrated in Fig. 44 with different types of filament, and the curves in Fig. 24 have been plotted to show the candle-power at different angles from the optical axis of lens.

As mentioned earlier in this paper, an enormous increase in candle-power has been obtained, even where the power consump-

tion has actually been decreased, by concentrating the illumination at the focus of the lens, instead of permitting a large spread of illuminated filament similar to Fig. 17 where a considerable percentage of the filament has little value for projecting light.

The use of two lamps in multiple as shown in Fig. 8 is somewhat uneconomical. The rear lamp is out of focus, and, even when provided with a reflector, can only give about 10 per cent. of the total beam candle-power; the rear lamp has been provided principally as a safety factor to furnish light in case the front lamp burns out. Of course, a "cut in" relay (Fig. 9) may be provided, to insure one fresh lamp being held in reserve and thus avoid all possibility of both lamps burning out at nearly the same time. The logical solution is to use only one lamp in each signal and renew all lamps at intervals, based on a careful observation of their life. By keeping an extensive record of lamp performance it is possible to forecast the life of lamps with considerable accuracy, and it is thought that lamp failures may, under this system, be reduced much below the percentage of failures now experienced with oil-burning lanterns. The few lamps which burn out before the date set for renewal will entail small delay, and can be reported by the engineers discovering them. A signal which fails to give any indication will always be interpreted as "Stop," and a burned-out lamp is, therefore, not a source of danger *where the signal pole or case can be seen*. In the daytime the background of a light signal is distinct, and there is no danger of an engineer passing a signal if the light is out. As the case and hood are painted black and are, therefore, inconspicuous at night, there is then nothing but the light to inform an engineer that he is approaching a signal, so that if this light were out he might pass the signal without knowing it. Moreover, the light signal is usually controlled by a relay or by a circuit controller of some sort as illustrated in Fig. 48, and to present a correct stop signal indication we must close a circuit and cause a lamp to burn—a principle entirely at variance with the best practice in signalling, which requires that a signal indicate *stop* whenever the circuit *fails* to close, so that a broken wire or imperfect contact cannot prevent the display of a red light. For this reason the author wishes to emphasize the advantages of using with a light signal an independent marker light *A*, Fig. 25, which shall be burning all the time, independently of the signal

indications. This marker may be an illuminated number plate or a lens, but it must not display any color which can be mistaken for a proceed or caution indication; as it is only necessary at night, it may, if desired, be of far lower candle-power than the signal indications; it must be located several feet from the powerful signal lights, in order that its indication be distinct at a distance of 800 or 1000 feet at night, and enginemen should be instructed that a combination of marker and signal is necessary for a correct night indication. Where a single signal is used we must depend upon the marker light for the final element of safety when

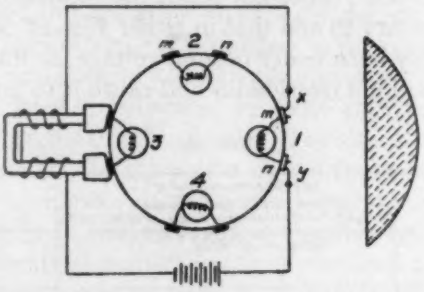
FIG. 25.

A is a marker light attached to a light signal.

the signal light is out at night, and no pains should be spared to make this marker light as reliable as possible. Assuming that signal lamps are used having a renewal period of three months, the marker lamps might be made of more rugged construction or burned at lower voltage, so that their average minimum life would be six months. Then by renewing the marker lamps at the same time as the signal lamps—once every three months—an increased factor of safety would be gained. In addition to this, there should be two lamps behind the marker light, one of these lamps always being held in reserve to be used in case the first lamp burns out. The second lamp may be cut in through the back contact of a relay, as illustrated in Fig. 9, or several lamps

may be mounted on a revolving base of magnetic material (see Fig. 26), which is operated by a coiled spring not shown in the figure, and held from moving by an electromagnet. In Fig. 26, lamp 1 is at the focus of lens, and the revolving base is held there by an electromagnet which is energized by the current passing through contacts *x*, *m*, *n*, *y* and the filament of lamp 1;

FIG. 26.



when this filament burns out, the electromagnet is de-energized and the base is caused to revolve by the spring until lamp 2 comes into focus and is lighted, the current through filament of lamp 2 again energizing the electromagnet and preventing further rotation of the base. A safety brake, not shown in the figure, is

FIG. 27.

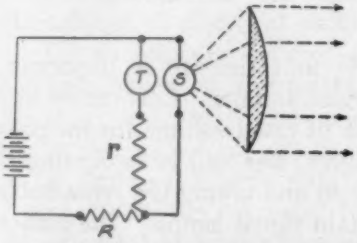
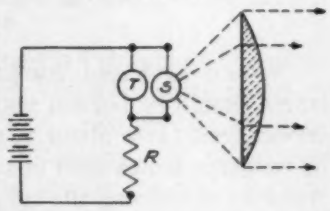


FIG. 28.



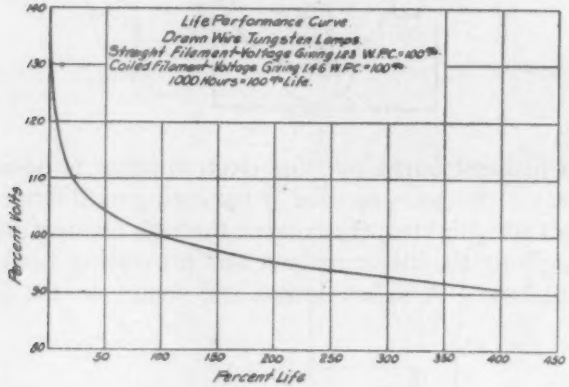
provided to clamp the base and prevent its revolving if the power is cut off the line.

The same result may be secured without using contacts, springs, or magnets, by arranging suitable resistances *R* and *r*, according to Fig. 27, so that when both lamp filaments *S* and *T* are intact *S* gets sufficient current to illuminate the lens and *T* is kept hot but not incandescent, but when *S* burns out enough

current will be forced through T to "light" this lamp. The filament of T is always hot; it has been claimed that a hot filament is less likely to be broken by vibration than is a cold filament.

Fig. 28 shows a variation of Fig. 27, the lamps being of different voltages, T being the higher voltage lamp. Thus when both filaments are intact the lower resistance of the two lamps in multiple causes greater drop in potential through resistance R, so that S burns but T does not reach the incandescent point. It is scarcely necessary to add that in either Fig. 27 or Fig. 28 lamp S must ordinarily burn under normal voltage, so that the breaking of filament T will not overload S and cause it to burn out.

FIG. 29.



Where long and comparatively uniform life is important, lamps should be burned under normal voltage. Laboratory and service tests favor about 90 per cent. of rated voltage for the class of tungsten lamps used in signal lights; this will be easily understood by examining the curve Fig. 29 and noting the remarkable effect of voltage on the life of certain signal lamps. The author does not intend this curve or the figures preceding to be taken as characteristic of all lamps; they are submitted as illustrating the undoubted necessity for reducing lamp voltage to secure increased life. The efficiency of the lamps is certainly decreased as the voltage is lowered (see Fig. 14). To arrive at any intelligent decision, each case must be handled on its merits, balancing the increased watts per candle-power against the decrease in expense of maintenance and lamp renewals.

(To be continued.)

ELECTROMAGNETIC RADIATION.*

BY

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THE Hertzian theory for the distribution of the electromagnetic forces and the radiation from a cylindrical oscillator finds an extensive application to problems in radio communication. The formulæ established by Hertz are applicable to antennæ, and are, therefore, used considerably by radio engineers in the study of the transmission of radio signals. The analysis, however, employed by Hertz in the derivation of the formulæ is beyond the mathematical equipment of the average radio engineer, and for some engineers it is altogether an impossible task to follow the various mathematical transformations required in the establishment of the final formulæ, and are, therefore, to that extent accepted on faith, without knowing the limitations and assumptions involved in the work.

It is the purpose of this paper to give a new method for deriving these formulæ in which only elementary mathematics is employed, and thus bring the discussion of the subject within the reach of the average engineer. It is also hoped that it will be of some interest to the experimental physicist who is interested in the subject of electrical oscillations.

Let us consider the case of a straight cylindrical conductor through which an alternating current $I \sin \omega t$ is passing, where $\omega = 2\pi \times$ frequency. The magnetic field surrounding the conductor does not reach out to infinity instantaneously, on account of the finite velocity of propagation of the electric and magnetic forces, hence the magnetic force at any point distance r from the axis of the cylinder lags behind the current by a time internal δt, and we therefore have

$$H = \frac{2I}{r} \sin \omega (t - \delta t) \qquad (1)$$

If we denote by u the velocity of propagation, and by r the radial distance to any point, we have

$$\delta t = \frac{r}{u} \qquad (2)$$

* Communicated by the author.

Substituting the value of δt from (2) into (1), we get

$$H = \frac{2I}{r} \sin \omega (t - \frac{r}{u}),$$

$$= \frac{2I}{r} \sin \frac{\omega}{u} (ut - r) \quad \ldots\ldots (3)$$

In all wave motion we have the relation

$$u = f\lambda = \frac{\omega\lambda}{2\pi}, \quad \ldots\ldots (4)$$

where f is the frequency and λ is the wave-length, hence equation (3) may take the following form:

$$H = \frac{2I}{r} \sin \frac{2\pi}{\lambda} (ut - r) \quad \ldots\ldots (5)$$

In the case of oscillatory currents, however, another element must be taken into consideration; namely, the radiation phenomena. Suppose we have the positive half of the wave of the current passing through the conductor setting up a positive magnetic field around the conductor; when the current reaches the zero point, the magnetic field is not reduced to zero simultaneously, since it requires a finite time for the magnetic field to travel back to the conductor. As a consequence, before all the positive magnetic lines of force collapse back on the conductor, a negative magnetic field is set up by the negative half of the wave of the current which repels the positive magnetic field and thus introduces the phenomena of radiation: that is, at some distance from the conductor the magnetic field is not stationary, but is continuously travelling away from the conductor into infinite space.

If we consider any spherical layer at some distance r from the axis of the oscillator, the magnetic flux within it is the difference between the number of lines of force which enter at the inner surface and leave at the outer surface.

Let r denote the inner radius of the spherical layer.

Let δr denote the thickness of the spherical layer.

Let B denote magnetic flux at inner surface.

We have for the magnetic flux at outer surface of the spherical layer $B - \frac{\partial H}{\partial r} \partial r$, and the total magnetic flux within the spherical layer is

$$B - (B - \frac{\partial B}{\partial r} \partial r) = \frac{\partial B}{\partial r} \partial r, \quad \ldots\ldots (6)$$

and the intensity of the magnetic force within the spherical layer is, therefore,

$$H' = \frac{\partial B}{\partial r} = \frac{\partial H}{\partial r} \quad \ldots\ldots (7)$$

Substituting the value of H from (5) into (7), we get

$$H' = \frac{2I}{r} \frac{2\pi}{\lambda} \cos \frac{2\pi}{\lambda} (ut - r) + \frac{2I}{r^2} \sin \frac{2\pi}{\lambda} (ut - r) \quad \ldots\ldots (8)$$

For considerable distances from the axis we may neglect the second term of the right-hand side of the above equation as being small in comparison with the first term, since it contains r^2 in the denominator, and we have

$$H' = \frac{4\pi I}{r\lambda} \cos \frac{2\pi}{\lambda} (ut - r) \quad \ldots\ldots (9)$$

Equation (9) gives the magnetic force for points in the plane perpendicular to the current element under consideration, and for any other points in space, as that marked P in the figure, we have

$$H' = \frac{4\pi I}{r\lambda} \cos \frac{2\pi}{\lambda} (ut - r) \sin \theta \quad \ldots\ldots (10)$$

The above expression represents the magnetic force due to a single element of the conductor, and for a conductor of length l we have

$$H = \int_0^l H' dl = H' l,$$

hence

$$H = \frac{4\pi I}{r} \frac{l}{\lambda} \cos \frac{2\pi}{\lambda} (ut - r) \sin \theta \quad \ldots\ldots (11)$$

In the derivation of the above expression for the magnetic field it was implicitly assumed that the current was uniform along the entire length of the conductor. To allow for the variation in the current distribution on the conductor we multiply equation (11) by a factor α, and so we finally have

$$H = \frac{4\pi I \alpha}{r} \frac{l}{\lambda} \cos \frac{2\pi}{\lambda} (ut - r) \sin \theta \quad \ldots\ldots (12)$$

In case of the Hertzian radiator whose length is very small

compared with the wave-length, we may put $a = \frac{1}{2}$, and equation (12) reduces to

$$H = \frac{2\pi I}{r} \frac{l}{\lambda} \cos \frac{2\pi}{\lambda} (ut - r) \sin \theta \quad \ldots\ldots (13)$$

For a sine distribution of the current on the oscillator,

$$a = \frac{2}{\pi}.$$

We can obtain the expression for the electric force around the oscillator by applying the principle of conservation of energy.

We have for the electromagnetic energy in an element of volume,

$$W_m = \frac{1}{8\pi} \mu H^2 \quad \ldots\ldots (14)$$

and for the electrostatic energy in the same element of volume,

$$W_e = \frac{K}{8\pi} E^2 \quad \ldots\ldots (15)$$

By equating the two equations (14) and (15) we get

$$E = \sqrt{\frac{\mu}{K}} H \quad \ldots\ldots (16)$$

For free space we have $\mu = 1$, and $K = 1$ or u^2, depending whether we express E in electrostatic or electromagnetic units, hence

$E = H$ in electrostatic units
$= uH$ in electromagnetic units

Substituting the value of H from (12), we get

$$E = \frac{4\pi I a}{r} u \frac{l}{\lambda} \cos \frac{2\pi}{\lambda} (ut - r) \sin \theta \quad \ldots\ldots (17)$$

and for a Hertzian oscillator we take $a = \frac{1}{2}$ and

$$E = \frac{2\pi I}{r} u \frac{l}{\lambda} \cos \frac{2\pi}{\lambda} (ut - r) \sin \theta \quad \ldots\ldots (18)$$

Equations (12) and (18) give the expressions for the magnetic and electric forces, in C.G.S. electromagnetic units, around a cylindrical oscillator. It will be shown further on that these expressions are identical with those given by Hertz.

ENERGY RADIATION.

Poynting established an important theorem concerning the energy transmission through an electromagnetic field, which is as follows:

If the energy of the electric strain and magnetic flux are

varying, then for any small element of volume in the field the amount of energy which enters each element of surface is measured by the product of the electric and magnetic forces resolved along each element of surface, multiplied by the sine of the angle between their directions, and divided by the numerical factor 4π. Integrated for the entire surface,

$$W = \frac{1}{4\pi} \int EH \sin \psi dS \quad \ldots\ldots (19)$$

where ψ is the angle between the direction of the electric and magnetic forces, and dS is an element of surface.

For some distance from the oscillator the electric and magnetic forces are at right angles to each other, and therefore $\sin \phi = 1$. Hence

$$W = \frac{1}{4\pi} \int EH dS \quad \ldots\ldots (20)$$

Suppose, now, we take a sphere of radius r described around the oscillator, and seek to determine the energy that escapes from that sphere. The energy radiated during the time dt from a spherical zone comprised between the angles θ and $\theta + \delta\theta$ is given by the expression

$$\delta W = 2\pi r \sin \theta . r d\theta . \frac{1}{4\pi} EH \quad \ldots\ldots (21)$$

and to obtain the total energy radiated during the time dt it is necessary to extend the integration of the above expression for the entire surface of the sphere,—that is, integrate between the limits o and π. Hence

$$W = \frac{2\pi r^2}{4\pi} \int_0^{\pi} EH \sin \theta d\theta dt \quad \ldots\ldots (22)$$

Substituting in (22) the values of E and H from (17) and (12), we get

$$W = 8\pi^2 a^2 I^2 u \frac{l^2}{\lambda^2} \int_0^{\pi} \cos^2 \frac{2\pi}{\lambda} (ut - r) \sin^3 \theta d\theta dt \quad \ldots\ldots (23)$$

But

$$\int_0^{\pi} \sin^3 \theta d\theta = - \left[\frac{1}{3} \cos \theta (\sin^2 \theta + 2) \right]_0^{\pi} = \frac{4}{3} \quad \ldots\ldots (24)$$

hence the energy that escapes through the entire sphere in the time interval dt is

$$W = \frac{32}{3} \pi^2 a^2 I^2 u \frac{l^2}{\lambda^2} \cos^2 \frac{2\pi}{\lambda} (ut - r) dt \quad \ldots\ldots (25)$$

The energy radiated in a complete period is

$$W = \frac{32}{3}\pi^2 a^2 I_2 u \frac{l^2}{\lambda^2}\int_0^T \cos^2 \frac{2\pi}{\lambda}(ut-r)dt \quad \ldots\ldots(26)$$

But

$$\int_0^T \cos^2 \frac{2\pi}{\lambda}(ut-r)dt = \frac{\lambda}{2\pi u}\left[\frac{1}{2}\frac{2\pi}{\lambda}(ut-r) + \frac{1}{4}\sin\frac{4\pi}{\lambda}(ut-r)\right]_0^T$$

$$= \frac{\lambda}{2\pi u}\frac{1}{2}\frac{2\pi}{\lambda}uT = \frac{T}{2} \quad \ldots\ldots(27)$$

hence

$$W = \frac{16}{3}\pi^2 a^2 I^2 u \frac{l^2}{\lambda^2} T \text{ ergs per period} \quad \ldots\ldots(28)$$

The energy radiated in one second is

$$W = \frac{16}{3}\pi^2 a^2 I^2 u \frac{l^2}{\lambda^2} Tf = \frac{16}{3}\pi^2 a^2 I^2 u \frac{l^2}{\lambda^2} \text{ ergs per second} \quad \ldots\ldots(29)$$

Expressing the current in ampères and the energy in watts, we have

$$W = \frac{16}{3}\pi^2 a^2 \frac{I^2}{100} \times 3 \times 10^{10} \frac{l^2}{\lambda^2} \frac{1}{10^7} = 1579 a^2 I^2 \frac{l^2}{\lambda^2} \text{ watts per second} \quad (30)$$

The energy radiated is directly proportional to the square of the length of the oscillator and the square of the current, and inversely as the square of the wave-length. For any particular value of $\frac{l}{\lambda}$ the energy dissipated by radiation is proportional to the square of the current in the oscillator, which is analogous to the case of energy dissipation by a resistance, and we may consider then the factor $1580 \frac{l^2}{\lambda^2} a^2$ as an equivalent resistance, and it is called the radiation resistance.

For $a = \frac{1}{2}$ we have for the radiation resistance

$$R = 394.8 \frac{l^2}{\lambda^2} \text{ ohms}$$

or in round numbers,

$$R = 400 \frac{l^2}{\lambda^2} \text{ ohms.}$$

For $a = \frac{2}{\pi}$,

$$R = 640 \frac{l^2}{\lambda^2} \text{ ohms.}$$

Hertz gave the following expressions for the electric and magnetic forces around an oscillator, and the energy radiation:[1]

The electric forces,

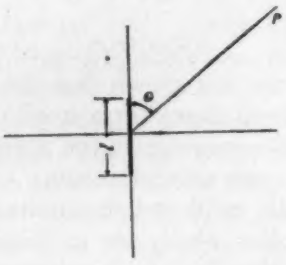
$$Y = \frac{\phi m^2}{r} \sin (mr - nt) \sin \theta \cos \theta,$$

$$X = \frac{\phi m^3}{r} \sin (mr - nt) \sin^2 \theta.$$

The resultant electric force is

$$E = \sqrt{X^2 + Y^2} = \frac{\phi m^2}{r} \sin (mr - nt) \sin \theta \quad \ldots\ldots (31)$$

FIG. 1.



The magnetic force,

$$H = \frac{\phi mn}{ur} \sin (mr - nt) \sin \theta \quad \ldots\ldots (32)$$

Energy radiation in one period,

$$W = \frac{16\phi^2\pi^4}{3\lambda^3} \quad \ldots\ldots (33)$$

where ϕ is the electric moment, the maximum charge on either end of oscillator multiplied by the length of the oscillator,

$$\phi = Ql \quad \ldots\ldots (34)$$

Q is the charge expressed in electrostatic units. Expressing ϕ in electromagnetic units, we have

$$\phi = Qul \quad \ldots\ldots (35)$$

[1] See J. A. Fleming, "Principles of Electric Wave Telegraphy and Telephony," second edition, chapter v.

If we denote by I the current in the conductor, and $\omega = 2\pi \times$ frequency, we have

$$I = \frac{dQ}{dt} = \omega Q,$$

and

$$\phi = \frac{Iul}{\omega} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (36)$$

In the notation used by Hertz and given in equations (31) to (33),

$$m = \frac{2\pi}{\lambda} \text{ and } n = 2\pi \times \text{frequency}.$$

On substituting the values of ϕ, m, and n as given above into equations (31) to (33), the equations will become identical in form with those given by (13), (18), and (30).

ANTENNÆ.

Practical experience has shown that the theoretical formulæ which have been derived above for a small oscillator may be applied with considerable accuracy in the study of the distribution of electromagnetic forces around antennæ of the different types that are now generally employed in wireless stations, providing we consider only points which are at some distance from the antenna. If we take the case of a single grounded vertical wire, we may consider the surface of the earth as the neutral plane of zero potential, corresponding to the neutral plane passing through the centre of a Hertzian oscillator, the antenna forming one-half of the oscillator and its image below the surface of the earth the other half of the oscillator. Obviously in this case it is only the upper half of the oscillator that contributes to the electromagnetic forces and the energy radiation, hence in applying the formulæ given above for this case we must use for l the length of the antenna and not twice its length, which is the length of the equivalent oscillator. Now, it can be readily shown that the fundamental free oscillation on a conductor, which is grounded at one end and open at the other end, has a wavelength which is four times the length of the conductor. The current has zero value at the open end and a maximum value at the grounded end, following a sine variation along the entire length. The average value of the current for the entire length of the conductor is $\frac{2}{\pi}$ times its maximum value, hence the value

of the factor α which enters in equation (30) is $\frac{2}{\pi}$. The energy radiated from the antenna during one period is

$$W = 640\, I^2\, \frac{l^2}{\lambda^2} \text{ watts} \ldots\ldots (37)$$

and the radiation resistance is

$$R = 640\, \frac{l^2}{\lambda^2} \text{ ohms} \ldots\ldots (38)$$

where l is the height of the antenna. The above formulæ may be also applied to the different types of branched antennæ, providing the proper value of l is used in each case.

RADIATION DECREMENT.

In the case of free oscillatory currents in an electric circuit, the electrical energy originally stored in the circuit is gradually dissipated by the resistance of the circuit. The amplitudes of successive oscillations gradually diminish in amplitude until the entire energy is used up. The logarithmic ratio of the amplitudes of two successive oscillations is called the logarithmic decrement of the circuit. If we denote by I_1, I_2, I_3, etc., the amplitudes of the currents of successive oscillations, we have

$$\frac{I_1}{I_2} = \frac{I_2}{I_3} = \frac{I_3}{I_4} = \text{etc.} = \epsilon^{\delta} \ldots\ldots (39)$$

where δ is the logarithmic decrement, and is expressed by the following formula:

$$\delta = \frac{R}{2Lf} \ldots\ldots (40)$$

where R is the resistance of the circuit expressed in ohms, L is the inductance of the circuit expressed in henry and f is the frequency of the oscillations. The value of δ as given by (40) is the logarithmic decrement per complete period. In the case of a vertical single-wire antenna grounded at the lower end, the fundamental wave-length developed by a free oscillation is four times the length of the antenna. We have

$$\lambda = 4l$$

and

$$R = 640\, \frac{l^2}{\lambda^2} = 640\, \frac{l^2}{16 l^2} = 40 \ldots\ldots (41)$$

For the frequency of the oscillations we have

$$f = \frac{u}{\lambda} = \frac{3 \times 10^{10}}{4l}, \quad \ldots\ldots (42)$$

and the value of the inductance is given by the expression

$$L = 2l\left\{\log_e \frac{2l}{r} - 0.75\right\} \times 10^{-9} \text{ henry}, \quad \ldots\ldots (43)$$

where r is the radius of the conductor. As an approximation we may neglect 0.75 in comparison with $\log_e \frac{2l}{r}$ in equation (43). Substituting the values of R, f, and L, from equations (41) to (43) in equation (40), we get

$$\delta = \frac{40}{4l \log_e \frac{2l}{r} \times 10^{-9} \times \frac{3 \times 10^{10}}{4l}} = \frac{4}{3} \frac{1}{\log_e \frac{2l}{r}} \quad \ldots\ldots (44)$$

Equation (44) gives the logarithmic decrement for the fundamental oscillations of the current,—that is, the quantity $\epsilon^{-\delta}$ gives the ratio of the amplitudes of two successive oscillations. Since the energy of each oscillation is proportional to the square of the current, the radiation decrement is twice the value given by equation (44). The ratio of the energies of two successive oscillations is $\epsilon^{-2\delta}$, and 2δ is therefore the radiation decrement. We have then

$$\delta_e = 2\delta = \frac{8}{3} \frac{1}{\log_e \frac{2l}{r}} = \frac{2.67}{\log_e \frac{2l}{r}} \quad \ldots\ldots (45)$$

The problem of antenna radiation was discussed by Dr. M. Abraham,[2] who treated the problem in a very original manner, and he obtained an expression for the radiation decrement of the fundamental frequency of the oscillations corresponding to equation (45), which is as follows:

$$\delta_e = \frac{2.44}{\log_e \frac{2l}{r}} \quad \ldots\ldots (46)$$

Equations (45) and (46) give very nearly the same value for the radiation decrement; they are exactly of the same form, differing only by a small numerical factor.

WASHINGTON, D. C.

[2] M. Abraham, *Physikolishe Zeit.*, 1901.

THE FLOW OF SANDS THROUGH ORIFICES.*

BY

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THE flow of dry sands and like substances through orifices, under varied conditions and different sand-heads, has not been studied sufficiently for predicting results. It is desirable to know (1) the rate of flow of dry sands under definite conditions, (2) the extent of the variation in flow under varying conditions, (3) the influence of the physical qualities of the sands, and (4) the form and size of required discharge-orifices to permit of unfailing flow or other desired results. So far as practicable it is desirable to have numerical constants at one's command to represent the separate influences that work upon the result. Such influences require separate recognition, and are made the objects of study described in the pages which follow.

Appliances for Measuring the Flow.—The three forms of appliance which were used for determining the rate of flow in the tests to be described are illustrated in Figs. 1, 2, and 3. The appliance shown in Fig. 1 was used with discharge-orifices of one-half inch or less in diameter. The arrangement shown in Fig. 2 was used with orifices larger than one-half inch diameter, and, in certain tests of a special nature, with orifices smaller than this. The appliance shown in Fig. 3 was used in certain small tests of limited application.

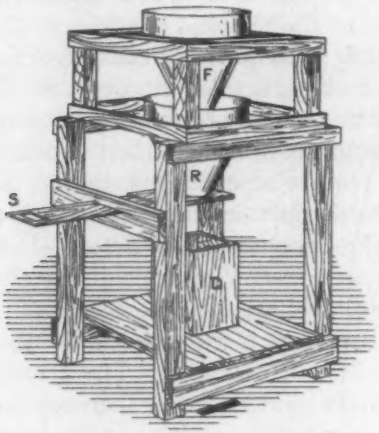
The appliances were checked, one against another, under various conditions, testing the same discharge-orifices in each. They were modified, moreover, in various ways to comply with the requirements of certain special tests which are to be described. Under all the regular conditions of operating, the depth of sand above the discharge-orifice was twelve times the diameter of the orifice.

In the apparatus shown in Fig. 1, the conical receptacle *R*, which is 12½ inches in diameter at the top, 3¼ inches at

* Communicated by the author.

the bottom, and 12½ inches deep, is the reservoir supplying the material to the discharge-orifice in the centre of the bottom. The orifice plates, in which the orifices are formed, are shown in Fig. 4, under the letters *j* to *q*. These, except where otherwise stated, are brass discs, with the orifices turned or drilled in the centre, forming a ring. The orifice plates fit interchangeably into a recessed seat in the centre of the bottom of the truncated cone *R*. Thus the bottom of the cone *R*, when the orifice plate is in place, is flat over a diameter of 3¼ inches. The discharge is controlled by the slide *S*. The upper cone, *F*, is used to supply material to the lower cone, *R*, and to regulate

FIG. 1.

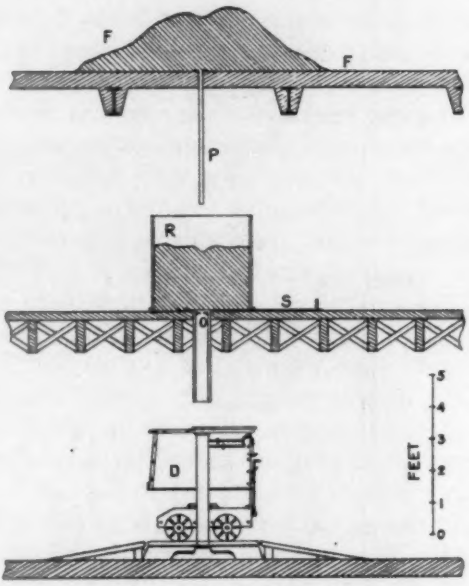


the level of the material in the cone *R*. The supply of flowing material enters the reservoir *R* through a regulated opening in the bottom of the cone *F* at the level desired.

In the arrangement shown in Fig. 2, the bin *R*, three feet in each of the three dimensions, supplies the material at the discharge orifice *O*. The orifice plates are interchangeable in this appliance as in the foregoing one. Here, as in the previous case, the orifice plate fits into a turned seat, and is thus supported in a horizontal position, with the aperture opening vertically downward. Material is supplied to the bin *R* from the floor above at *F*. The bin *R*, shown in the figure, is replaced by one of another form, deeper, and of smaller area, for certain

special tests on the influence of the sand-head which are to be described. Different ways of supplying the material to the bin *R* were examined and made use of according with the purpose. The pipe *P* was used as a means of supplying the material in the usual tests. When it was necessary to break the impact of material entering the bin *R* through the pipe *P*, a large tee pipe-fitting was attached to the lower end of the pipe. The material discharged from the standard orifice, at *O*, was received in the car *D*, or in other tared receptacles in accord with the quantity for weighing.

FIG. 2.



The arrangement shown in Fig. 3 was used for certain small tests with small orifices. It was used whenever a volumetric measurement of the flowing material was directly sought. Further use was made of the arrangement in determining the density of sands in the dry, aggregated state, as will be described.

Outline of Tests to Determine the Flow.—Provision is made in the appliances shown in Figs. 1 and 2, to secure a full

and regular stream of the sand or other material, flowing under constant conditions, vertically downward, through an accurately-formed orifice of the selected size and shape. Provision is further made to arrest or divert the flow and to receive the material, for an accurately-timed period, in a receptacle for accurate weighing.

To determine the flow by means of the appliance shown in

FIG. 3.

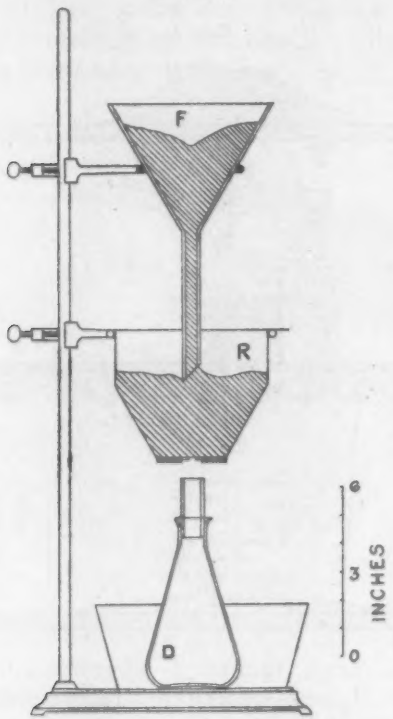


Fig. 1, the slide *S* is first drawn, and the stream allowed to become regular, whereupon, at a definite moment, the empty receptacle *D* is inserted beneath the stream. The flowing stream then entering the receptacle is allowed to continue the desired time, as measured by a stop-watch. The stream is then arrested by throwing the slide *S*. The quantity of material thus collected is weighed, and from the weight is learned the volume as based upon the known density of the aggregated material, determined

under conditions to be described. The volume of material which has passed the orifice of known area in a given time thus being known, the velocity of the stream, in feet per second, is calculated.

To determine the flow by the use of the arrangement shown in Fig. 2, the stream is started and stopped by means of the slide *S*. Here the duration of the flow is relatively long. The time is measured accurately with the stop-watch. In certain tests with small orifices, to determine the velocity of flow under a varied head, the stream was made continuous, but was deflected for definite periods at fixed intervals into a receptacle below.

In using the appliance shown in Fig. 3, the stream was made continuous. The small size of the containing vessels and the manner in which the apparatus was used permitted of accurate time-measurement without the special mechanical means to divert or arrest the stream. The appliance was used primarily as a means of supplying a stream of material for the determination of the density, as will be described, but was used in a limited way for obtaining results by volume to accord with those by weight in the usual tests.

In the determination of the flow directly by volume, the flask *D*, graduated, and of 325 c.c. capacity, was inserted at the designated moment beneath the flowing stream. The time was noted of the instant at which the stream began to enter and at which the flask became filled to the graduation mark at the top. The height of the fall of the material from the orifice into the flask was adjusted, as well as could be, to accord with that of the same material under the conditions of determination of density that are adopted as standard and are later to be described. When thus standardized, the appliance as here shown was found suitable to use for certain tests conducted in a series, with an orifice of one size, on materials of one type.

The sand materials which were tested were prepared in all cases by dry sizing upon closely-graded wire screens. The estimate of the diameter of the particles was made by direct measurement under magnification. A comparison of this measurement with the screen measurements was made in every case, and in certain cases by volumetric displacement of numbers of the particles. The results of the average direct measurement are adopted as the best expression of size.

The Precision of Measurement and the Accuracy.—The separate observations of flow were repeated in each case to obtain four to nine independent results. These results were averaged, and the average deviation from the mean in each case was observed. In these tests an aggregate of ten minutes was adopted as a minimum duration of flow, the time beyond this being given according to the requirement shown by the deviation among single observations. The time was measured with a correct stop-watch, giving precision to ⅕ second.

The limit to the accuracy of the observations is imposed by the construction of the discharge-orifices, and by the assurance of quality and the measurement of the coarseness of the sands. The orifices are accurate in construction to 1/1000 inch in dimensions. The limit to the accuracy of the construction and measurement of these introduces the possible error of one part in approximately 250 with the ¼-inch orifice, to one part in approximately 3000 with the 3-inch orifice. Certain of the smaller orifices were duplicated for replacement and comparison. The precision as to time-measurement and weighing exceeds that necessary to accord with the accuracy of the orifices. With materials of varied coarseness, tested for a comparison of the influence of the size of the grains, the limit to accuracy is imposed by the sizing and preparation of the material and the estimate of the size of the constituent grains.

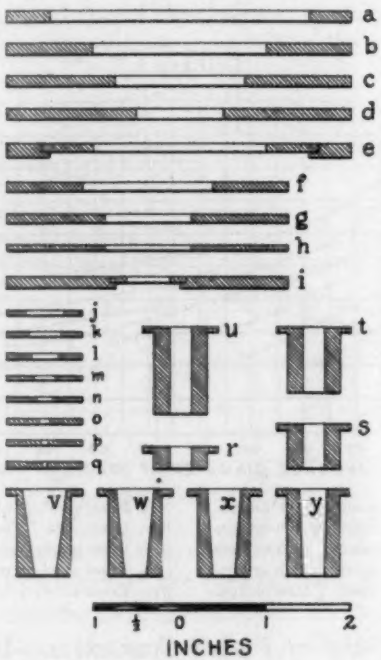
The deviation in the rate of flow was different in the observations upon different substances, as will be described, and ranged from one part in thirty to the limit of precision of the observations, in which one part in one thousand was sought wherever compatible with the exactness of the orifice or with the uniformity and character of the material. With a long duration of flow the deviation among observations was shown to be less wide, the decrease, however, not continuing with greatly increased time. The duration of flow employed was chosen as ample to equalize the brief irregularities of flow, and to be consistent with the accuracy in the remaining conditions.

The value of the acceleration of gravity at the place of determination approximates 9.7996 metres per second. The atmosphere is that of a dry interior. The daily variation in the humidity of the interior atmosphere is unrecorded, as

are also the variations in barometric pressure; the differences in temperature are between 12° and 22° C.

The Discharge-orifices.—The discharge-orifices chiefly intended for study were of circular cross-section. In addition to these, a square, a triangular, and certain oblong forms were used for comparison. The orifices were prepared with a smooth finish, made as nearly uniform as possible in all. With the exception of the few special forms to be described, they were

FIG. 4.

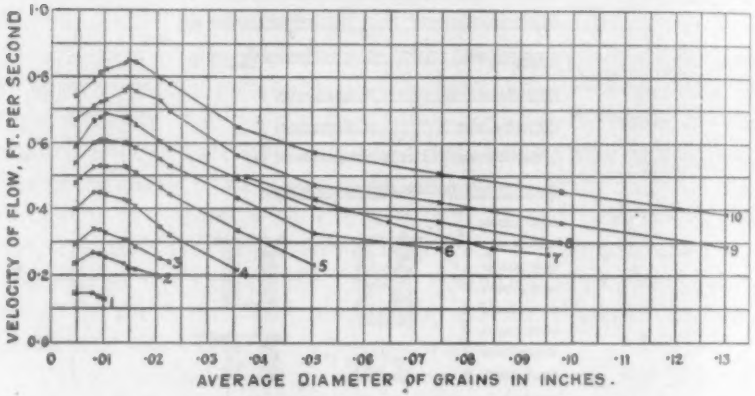


made without taper, by cutting the aperture in the centre of round, turned discs of rolled brass. These discs were of 1/16 inch thickness for orifices of ½ inch or less in diameter, 3/32 inch for those between ½ and 2 inches, and ⅛ inch for sizes larger than 2 inches. Each fitted into a turned seat provided in each of the forms of appliance, the smaller orifices being extended by means of turned rings to the size of the seat in the larger apparatus, as shown under the letter *i* in Fig. 4, the de-

sideratum in each case being to maintain a flat bottom of the receptacle to the sand material contained. The orifice plates, thus interchangeable, remain rigid in a horizontal position such as to direct the stream vertically downward.

Several orifices, other than of the round forms described, are shown in Fig. 4. Under the letters *v* to *y* are round, tapered orifices. Those lettered from *r* to *u* are of ¼-inch diameter, circular in cross-section, and of varied length. The triangular orifice, two rectangular forms, and a round orifice not shown were made of a uniform cross-sectional area of one-quarter of one square-inch.

DIAGRAM I.



1. River sand, $\frac{1}{16}$ inch orifice.
2. River sand, $\frac{1}{8}$ inch orifice.
3. River sand, $\frac{1}{4}$ inch orifice.
4. River sand, $\frac{1}{2}$ inch orifice.
5. River sand, $\frac{3}{4}$ inch orifice.
6. River sand, $\frac{1}{16}$ inch orifice.
7. Lead shot, $\frac{1}{8}$ inch orifice.
8. River sand, $\frac{1}{16}$ inch orifice.
9. River sand, $\frac{1}{16}$ inch orifice.
10. River sand, $\frac{1}{4}$ inch orifice.

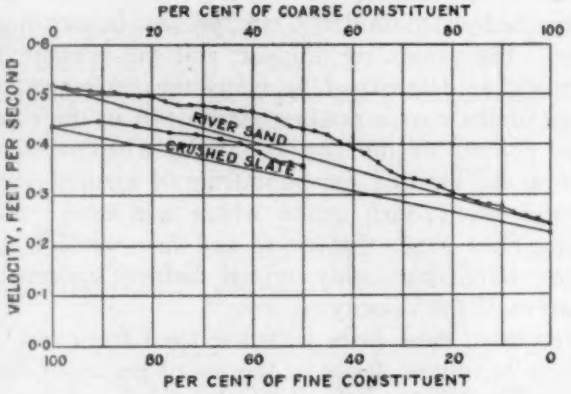
Tests with Sand of Varied Coarseness.—Diagram I shows the velocity of flow, in feet per second, of river sand, in passing round discharge-orifices, after being sized as closely as possible by dry screening. In comparison is shown the velocity of lead shot, after being carefully prepared and measured as described under Table I.

The river sand here used consists of naturally worn and rounded grains, rendered free from dust or clotted clay particles by washing and mechanical treatment, and freed from moisture by long exposure to a dry atmosphere. The sized products of

the sand were obtained by a systematic and thorough dry-sizing treatment, upon measured, closely-graded, brass-wire screens, and the average diameter of the grains is arrived at in an average of the measurements of many of the particles. The orifices were of turned brass, without taper, as shown under the letters *i* to *q* in Fig. 4, and were so placed as to direct the stream vertically downward in the apparatus shown in Fig. 1.

The results in velocity of flow were derived from the weight of sand discharged during periods of ten minutes, or shorter periods aggregating ten minutes or more, and were calculated from this weight and from the known specific gravity of the material in the dry, aggregated state. The limit to the accuracy

DIAGRAM II.



of the tests is reached in the variability in the quality of the materials. The precision of the observations as to time, weighing, and measurements exceeds one part in three hundred.

The Effect of the Mixture of Sizes.—Diagram II shows the effect upon the velocity of flow of a disparity in the size of the grains of sand. Sized products, coarse and fine, of river sand in one series of tests, and of crushed slate in another, are mixed in different proportions to observe the effects of the mixture of sizes upon the velocity of flow.

Diagram II represents in ordinates the velocity of flow through a ¼-inch round orifice, in feet per second, and in abcissæ the per cent. of coarse and of fine grains in the mixture. The straight line between the two extremes shows the velocity

as it would be if proportionate to the amount of each sized product composing the mixture. The two curves represent the two types of material,—river sand in the one case, and crushed slate in the other.

The river sand here used was identical in quality with that described in connection with Diagram I. Of the sand, two closely-sized products obtained with graded screens were used, which differed only in regard to coarseness. The average diameter of the particles, as determined by measurement, was .0503 inch in the case of the coarse and .0149 of the fine sand. The two products, coarse and fine, were then combined in varied proportions by weight, as represented in the diagram. The combined products, in each case, were then mixed thoroughly to give the uniformity sought.

The crushed slate, similarly, was present in two degrees of coarseness. The grains are angular, and the average diameter of the grains, as determined by many measurements, is .0468 in the case of the coarse product, and .0166 in the case of the fine. The coarser of the two materials, when unmixed with the fine, is at the limit of size permitting of assured, continuous flow through the ¼-inch orifice which was used. As in the case of the river sand, the coarse and fine sands in different proportions were thoroughly mixed before undertaking the determination of the velocity.

The results in these cases were averaged from nine or more observations by volume, taken by the use of the apparatus shown in Fig. 3. The results were checked in some of the cases by observations based upon weight, in which the specific gravity of the mixture was determined by the method adopted as standard throughout the work, and to be explained. The deviations of the single observations from the mean, in the present instance, were for the most part less than one part in one hundred in the case of the river sand, and with the finer product of the slate, but increased in the case of the coarse slate to one part in thirty, with more than 50 per cent. coarse material present, beyond which the curve is not extended.

The Influence of the Size and Surface of Spherical Pellets.—Table I shows the results of tests with lead shot, flowing from a ⅜-inch round orifice. The shot is chosen as a material composed of particles relatively uniform in shape.

The velocity shown in Table I is calculated from the mean observed weight of shot flowing during periods of two minutes, the calculation being based upon the density of the material under constant conditions, as will be described later. The density of the shot, which varies in the aggregated mass with the condition of the surface of the pellets and depends upon the manner in which the material is prepared for the observations, is given in the fifth column in Table I, and ranges from 6.64 to 6.80. The diameter of the approximately spherical pellets of shot, as shown in Table I, was derived by weighing together 100 of the pellets and calculating from the average weight of these, and upon the basis of the determined specific gravity of the lead, assuming the pellets to be spherical. The average variation in the diameter from the mean was obtained by the separate weighing of ten of the pellets of each kind.

TABLE I.

Table Showing the Velocity of Flow of Lead Shot, of Varied Sizes, through ⅜-inch Round Orifice.

The diameter of the pellets of shot.				The density of the shot in mass.	Average velocity in feet per second.		
Average of 100 pellets.	Maximum observed.	Minimum observed.	Average deviation from the mean.		In the condition purchased.	After washing and drying.	After washing and drying and coating with graphite.
.0952	.0964	.0930	.0009	6.802	.264	....	.265
.0850	.0861	.0843	.0008	6.722	.280	.266	.284
.06488	.0664	.0629	.0010	6.648	.364	.341	.363
.05057	.0532	.0448	.0014	6.761	.413	.408	.433
.03710	.0401	.0259	.0022	6.645	.504	.480	.498

The portions of shot of different size were all mechanically treated in order to produce a uniform condition of the surface. After the first observations of the velocity of the material in the original condition, the portions were treated alike by agitation with distilled water and soap as a detergent, then rinsed with water, followed with alcohol, and finally dried at 100° C. After testing in this condition to observe the velocity of flow, each portion was treated with graphite to thoroughly coat the pellets. The results upon the material as thus treated are shown in Table I.

The apparatus used was of the form shown in Fig. 3, except that a larger and open receptacle was used below the orifice for collecting and weighing. The operation was conducted otherwise, as is described in explanation of Table I. Here, however, with relatively little material, no mechanical attachment was required to arrest or start the stream, it being satisfactory to collect the flowing material in the required time by inserting and removing the receptacle beneath. The results as averaged are accurate to one part in four hundred. These are illustrated also in comparison with those obtained with sand in Diagram I.

The state of the surface of the shot was known to be an important influencing condition, determining in a large measure the coefficient of friction and the cohesion of the separate particles and thus exerting an important influence upon the density of the material and upon the quantity discharged. To observe the effects of extremes, and to judge as to requirements of prepared surfaces, tests were made, with results shown in Table II.

TABLE II.

Table Showing the Effect of the State of the Surface of Pellets of Lead Shot upon the Velocity of Flow.

The quality of the surface of the shot pellets.	Average velocity in feet per second.
In the original condition	.364
Slightly damp	.338
Moist	.295
Washed and dry	.341
Coated with rosin	.317
Freshly coated with graphite which is present in excess	.380
Freshly coated with graphite with excess graphite removed	.364

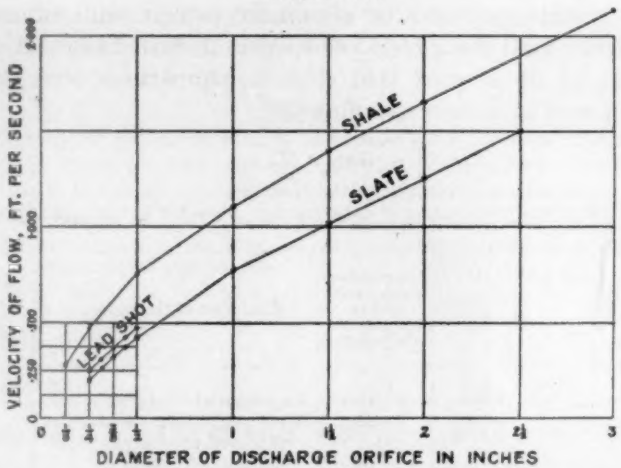
Table II shows the effect of the varied surface conditions upon the velocity of flow of lead shot through the ⅜-inch round orifice. The shot pellets were .06488 inch in diameter, and varied from the mean approximately one part in sixty. The velocity, as before, was determined by weighing the material collected in a given time, calculating the velocity from the area of the orifice and the density of the material in the state prepared for the special observations as will be described. The results are accurate to one part in two hundred.

The Size of the Orifice Related to the Velocity of Flow.—Tests were conducted to show the influence of the size of round orifices upon the velocity of flow. Diagram III shows the

velocity of flow of closely-sized, crushed slate, of fine-crushed shale, and of lead shot in passing round orifices of varied sizes.

The crushed slate represented in Diagram III was dry from long contact with the air after close sizing with wire screens. The particles were irregular and angular in shape, and were .0468 inch in the average diameter of the average grains. The velocities plotted are averaged from four to nine observations, according in number with the variation in flow and the deviation of the single observation. The averaged results may be considered accurate to one part in three hundred, while the precision as to time and weight considerably exceeds this. The sand-head, as in all the regular tests, was twelve times the diameter of the orifice employed.

DIAGRAM III.



The crushed shale represented in the above diagram was crushed and screened to exclude particles incapable of passing a screen of .014 inch (40-mesh) opening. The purpose was to work with fine-crushed material with a wider range of orifices. The material was composed of irregular grains, and included the undersize. The size and quality of the material were judged by screen tests performed upon different samples, and the portions employed for tests were so mixed as to represent material of a uniform quality and kind. The apparatus used in the tests upon the two sand materials is shown in Fig. 2, and was employed

in the manner previously described. The round orifices are shown in Fig. 4 under the letters *a* to *d* and *i* to *o*.

The lead shot represented in Diagram III is of the quality previously described under Table I. The velocity is derived from the averaged weight flowing during periods of two minutes. The averaged diameter of the pellets is .0649 inch. The surface of the pellets is in the state prepared in manufacture for the trade. The results are accurate to one part in 250.

Tests of Materials of Varied Density.—The velocity of flow of several substances of varied specific gravity was determined for the purpose of comparison. The results obtained with lead shot, as a material of high density, and mustard seed, of nearly similar spherical shape and of low density, were found best to illustrate the effects. With these materials many of the interfering conditions could be eliminated which with other substances obscured the effects of density alone. Table III shows the velocity of flow of lead shot in comparison with that of mustard seed of a corresponding size.

TABLE III.

Showing a Comparison of the Velocity of Flow of Lead Shot and of Mustard Seed, of the Same Size, Passing a Round Discharge Orifice of ⅛ inch Diameter.

Substance.	Diameter of pellets.	Approximate mean variation in diameter of the pellets.	Condition of the surface.	Average velocity in feet per second.
Lead shot.....	.0850	1 : 100	As prepared in manufacture	.280
Lead shot.....	.0850	1 : 100	After agitation with the mustard seed and graphite, and separating.	.286
Mustard seed..	.085	1 : 30	The condition in which the material existed before the surface alteration.	.301
Mustard seed..	.085	1 : 30	After agitation with the shot and graphite and separating.	.282

To obtain the results of Table III, the grains of seed and the pellets of lead shot were selected of a size as nearly as possible identical. To prepare the seed, an adequate quantity was winnowed to remove dust, and sized as rigidly as possible to correspond with the nearest size of shot available. The seeds were further examined and selected by permitting them to roll

slowly down an inclined surface to expose repeatedly to the attention all that were of imperfect form. The diameter of the shot was determined by calculation based upon the combined weight of one hundred of the pellets of determined density, as previously described. The diameter of the mustard seed could not well be determined in a similar manner, by weight, on account of the variability in density of the different seeds. The size was measured as accurately as possible by means of a micrometer gauge, and also by checking by placing the round seeds, side by side, in a V-shaped groove and measuring the combined diameter of samples of fifty or more. The specific gravity of the lead shot, in the aggregated mass, inclusive of the interstitial air-space, was 6.722, while that of the mustard seed was 0.7276 in the corresponding condition. The diameter was 0.085 inch, that of the shot being more nearly uniform in the mass, and in the spherules themselves, and thus capable of closer approximation.

TABLE IV.

Table Showing the Velocity of Flow of Samples of River Sand and of Beach Sand through Round Discharge-orifices of Identical Size and Form Composed of Different Materials.

Material of the ¼-inch orifice.	Average velocity of beach sand, composed of grains averaging .026 inch diameter.	Average velocity of river sand, composed of grains averaging .023 inch diameter.
Hard rubber	·419	·394
Brass	·441	·422
Babbitt's metal	·453	·431

The head, as in other tests with the ⅜-inch orifice, was 4½ inches. The orifice was round, of brass, and identical with that of this size previously used and shown under the letter *k* in Fig. 4. The time of flow for each observation approximated one minute, depending upon the velocity, and was measured to ⅕ second precision. The results are averaged from some nine observations in each case, and as thus averaged and tabulated are accurate to one part in one hundred.

The Material of Discharge-orifices.—Round discharge-orifices of ¼ inch diameter were made of hard rubber, and of Babbitt's metal for comparison with those of brass. Table IV shows the velocity of flow observed with samples of beach sand and of river sand in passing these orifices.

The round orifices by which the above results were obtained were of ¼ inch diameter, cut without taper through material of 1/16 inch thickness, and were of the form shown under the letter *m*, Fig. 4. They are of the same degree of accuracy as the brass orifices previously described, and are prepared as nearly as possible of a uniform surface finish among the different materials from which they are made. The sands used in the tests with these orifices were the closely-sized beach sand and river sand used in previous tests. The beach sand is composed of rounded grains of .026 inch in average diameter. The river sand is composed of grains of .023 inch average diameter. The results in velocity as here averaged and tabulated are accurate to one part in two hundred.

TABLE V.

Table Showing the Velocity of Flow of Beach Sand, Composed of Grains of .026 Inch Average Diameter, with Round Discharge-orifices of ¼-inch Diameter, of Varied Length and Contraction.

The designating letter of the orifice, referring to Fig. 4.	Length of the orifice-tube, in inches.	Diameter of the discharge-orifice at the top, in inches.	Diameter of the discharge-orifice at the bottom, in inches.	Average velocity in feet per second.
r	¼	¼	¼	0.44
s	½	¼	¼	0.44
t	¾	¼	¼	0.44
u	1	¼	¼	0.45
y	1	5/16	¼	0.86
x	1	3/8	¼	1.09
w	1	7/16	¼	0.94
v	1	½	¼	0.82

The Effects of Tapered and of Elongated Orifices.—Table V shows the velocity of flow of beach sand in passing ¼ inch round orifices of different forms as indicated. The average velocity is expressed in feet per second.

The round discharge-orifices here used were of turned brass, and were of accuracy corresponding to that of the orifices previously described. The tests are similar to the preceding ones in method. The material is a portion of the sized beach sand previously described, composed of particles of .026 inch in average diameter. The results as here averaged may be regarded accurate to one part in two hundred.

The Influence of the Cross-sectional Shape of Orifices.—The effect of certain differences in the cross-sectional shape of orifices is shown in Table VI, for one kind of material and one size of orifice.

TABLE VI.

Table Showing the Influence of the Cross-sectional Shape of the Discharge-orifices upon the Velocity of Flow. (The Area of Each of the Five Orifices is Equal to One-Quarter of One Square Inch.)

Shape of orifice.	Velocity in feet per second.
Round	.482
Square	.454
Rectangular (⅜ by ⅔ inch)	.436
Equilateral triangular	.376
Rectangular (¼ by 1 inch)	.311

Table VI shows the velocity of flow of a uniform, closely-sized, crushed slate, issuing from orifices of uniform cross-sectional area but of varied cross-sectional shape. The orifices were cut through ⅛-inch brass plate, and were made to conform in accuracy with those previously described. The apparatus is shown in Fig. 1. The crushed slate, which is composed of grains of .0468 inch in average diameter, has been described previously. The results as averaged may be regarded accurate to one part in two hundred.

The Sand-head.—The practical influence of a varied sand-head upon the velocity of flow was tested with a variety of materials, under a variety of conditions, the details of which scarcely justify description in this place. The sand-head examined ranged between a height equalling twice the diameter of the discharge-orifice to one of seven feet. The orifices used were round, of ¼ to 2 inches in diameter. The effects observed under the varied head were in all cases relatively slight, being less than one part in fifty from the mean under any of the conditions of varying head with thoroughly dried material. The apparatus used for the tests, apart from certain modifications of the feeding bin above to obtain the column and the supply required, is shown in Fig. 2.

The effects in most cases were not influenced uniformly by the head. For the most part a retardation of the flow resulted from an increase of the head—an effect which appeared attributable to the compacting of the sands under the increased pressure

of a high column, and the segregation known to occur at the surface, particularly effective under the necessary conditions incident to a low column. A series of results upon fine, sized sands passing the ¼-inch orifice was obtained in which the difference in head, between one-half inch and seven feet, was not distinguishable from the usual deviations observed under constant head.

The Effect of the Surface Contour.—A series of tests on a small scale was conducted to examine the effect of the contour at the surface and the influence of the shape of the supply receptacle. Fig. 5 illustrates the results.

FIG. 5.

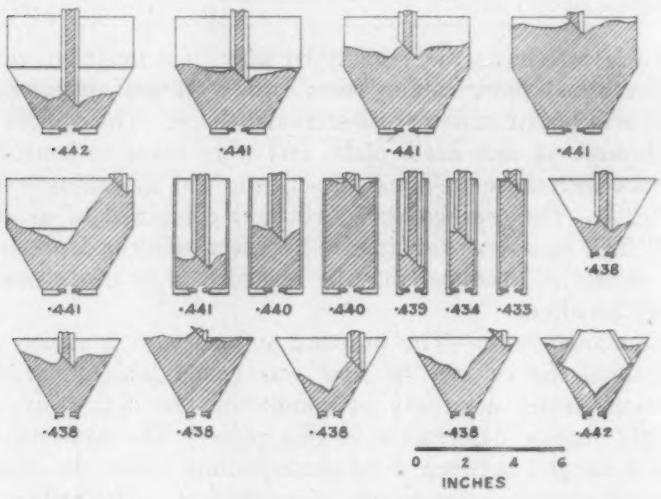


Fig. 5 represents vertical sections of the receptacles of sheet metal supplying the flowing sand to the brass orifice at the bottom. The round, brass discharge-orifice is of ¼ inch diameter, and of the form shown under the letter *m*, Fig. 4. The material tested is the closely-sized beach sand composed of particles .026 inch in average diameter, similar in kind to that previously used. Of the supply receptacles, two are seen to be truncated cones. The smaller cone is of ⅞ inch diameter at the bottom, the larger cone 2¼ inches. Two of the receptacles are cylindrical, one being two inches in inside diameter, the other, one inch. The sand-head is indicated by the shaded portion of

the section, and ranges from one inch to four, in differences of one inch in the different cases. The material is supplied to the different supply receptacles from a funnel above, the position of which is indicated in each figure by showing the lower extremity of the stem at the surface of the material. The velocity of flow through the ¼-inch brass orifice, in feet per second, is shown in numerals beneath each figure representing the conditions. The results averaged and shown are accurate to one part in four hundred.

TABLE VII.

Table Showing the Specific Gravity of Typical Sands, and Other Substances.

Material.	Dimensions in inches of the rectangular screen-openings through which the material was incapable of passing.	Dimensions in inches of the rectangular screen-openings through which the material passed.	Specific gravity of the dry, loose material, under the conditions of compacting described.	Specific gravity of the solid.	Ratio of the specific gravity of the aggregated mass to that of the solid.
River sand..	.014	.021	1.376	2.71	508 : 1000
River sand..	.007	.008	1.338	2.72	491 : 1000
Beach sand..	.014	.021	1.432	2.66	538 : 1000
Crushed slate	.033	.042	1.380	2.75	502 : 1000
Crushed shale	.000	.014	1.256	2.61	481 : 1000
Lead shot...	.063	.067	6.722	11.13	604 : 1000
Pumice stone	.033	.042	0.504	0.87	579 : 1000

The Density of the Materials.—In all the foregoing observations it has been considered desirable to express the capacity of the discharge-orifices in terms of velocity. The velocity indicated applies thus to the volume of dry sand or like substance in aggregated mass of known density passing the orifices in a given time. The velocity, so stated, is computed for the cross-sectional area of the orifice which is definitely known in each case. Results so expressed can be converted into terms of quantity or weight by making use of the known density of the material. The quantity of material flowing in all ordinary tests was determined by weight, and from this weight was calculated the volume, as based upon the determined specific gravity of the material in the state of aggregation adopted as standard. Accordingly a study was made of the interstitial space of the materials for the adoption of a state of density to be regarded standard in the various tests.

To obtain the material in a uniform condition of compactness, suitable for a constant determination of the density, the particles were allowed to collect in a given receptacle in a uniform manner, becoming compacted only by their fall through a known distance. In this prepared state of aggregation, the density of all materials was determined as a basis for the estimation of the velocity of flow. The average density of certain of the typical materials is shown in Table VII.

The Method of Determining Density.—The material was collected for the determination of density by being permitted to flow, vertically, by gravity, through a discharge-orifice capable of yielding a continuous stream, and the stream received below the orifice, in a stationary cylindrical receptacle, in which the weight and volume were subsequently determined in the state of compactness thus acquired by the particles in lodgement. The orifices used in each case were selected from a given series of orifices graded in differences of ⅛ inch diameter. These were required to be commonly eight or more times the diameter of the particles. The cylindrical receiving receptacles were prepared of a size to accord with the series of orifices, and were tared, standardized, and thus in accord with the coarseness of the given material. The cylinders were made of sheet metal, and were in depth twelve times the diameter of the chosen orifice, and in diameter ten times. They were supported in an upright position upon the closed end, distant below the orifice sixteen diameters of the orifice, the entire top of the cylinder being open. The material thus collected in the receptacle was afterward levelled by scraping off the excess above the rim at the top with a bevelled straight edge before disturbing the content in a way to alter the density. The receptacle, with its content, was then weighed, and the density of the material calculated from the known capacity of the receptacle. The observations were concordant in most cases to one part in two hundred. The determinations were repeated to obtain an average result consistent in exactness with the tests to be performed upon the materials.

Moisture.—Tests were conducted to show the influence of moisture in quartz river sand, shale, and other materials in different states of desiccation. The results show an increasing

velocity with an increasing degree of desiccation. The state of extreme desiccation is found to be insufficiently permanent to yield concordant results in open tests. In the recorded tests the materials are dry from long contact with dry air at the ordinary interior temperature of 17 to 20° C. A degree of uniform drying is thus brought about at which the hygroscopic quality of the surface of the particles and the desiccating effect of the dry atmosphere at the ordinary temperature are in such equilibrium as to occasion no appreciable change in the state of the material by exposure to the atmosphere during the tests.

The Rate of Discharge.—The weight of material passing an orifice in a given time may be calculated for round orifices from the results in velocity as shown in the diagrams and tables. For orifices of shape other than the round a somewhat different velocity would be found, as it suggested for one size and kind of material in the results of Table VI.

To calculate the weight from a known velocity, let W' represent the weight in pounds of a given material having the specific gravity s, in the dry loose state of aggregation, that will flow in t seconds, through an orifice a' square feet in area, with a velocity of v feet per second, where k is the weight in pounds of one cubic foot of water. The weight in avoirdupois pounds, accordingly, is as follows:

$$W' = vta'sk \qquad (1)$$

Taking 62.42 pounds as the weight of one cubic foot of water at 0° C., the weight W' of material of specific gravity s, having a velocity of v feet per second, that will be discharged in one second through any orifice of area a' square feet is as follows:

$$W' = 62.42\ vsa' \qquad (2)$$

Adopting the more convenient units, in which W is made the weight in pounds of material that the orifice will discharge each minute, v remains the velocity of flow in feet per second, but in which a is the area of the orifice in square inches, the following equation is obtained:

$$W = 26.008\ vsa \qquad (3)$$

For round orifices of diameter d inches, the corresponding equation, showing the weight in pounds per minute, is as follows:

$$W = 20.43\, vsd^2 \qquad (4)$$

Conclusions.—The following deductions may be based upon the results of the foregoing tests:

The uniformity of flow of sands through discharge-orifices is influenced by the dampness, fineness, and general quality of the material. The momentary irregularity of flow is perceptible to the eye in the case of orifices that are small relative to the coarseness of the material. With long periods of observation, in the case either of large or of small orifices, a smaller but persistent variability is found to exist which is not materially diminished by greatly prolonging the time. The deviations from a uniform flow draw the attention to the manner of supplying the material to the orifice, the compacting, the head, the shape and size of the supplying receptacle, and the time during which the material is permitted to remain at rest before the flow begins. Uniformity is greatest in the case of substances least compacting under pressure, and under conditions of flow that loosen the material above and near the orifice. It is favored by thorough dryness, rounded particles, and a low sand-head. Observations deviate less than one part in six hundred in the case of river sand of .01 inch diameter, under a sand-head of three inches, flowing five minutes through round orifices of ¼ inch diameter; while under the same conditions, but with angular or damp material, deviations exceed one part in fifty.

The velocity of flow under the existing conditions of gravity is governed chiefly by the size of the orifice and the size of the grains. Other important influences are the shape and surface condition of the grains and the shape of the orifice. Other conditions to be mentioned in the present summary exert a less marked influence.

The size of the grains influences the velocity of flow, causing, with the increase in size, a decrease in the velocity. This is shown in the case of river sand in Diagram I. There is here observed a maximum velocity at which the ratio of the diameter of the grains to that of the orifice ranges from 1 : 15 to 1 : 30 approximately. With finer material the velocity quickly drops

from this maximum, while with coarser the drop is seen to be gradual and, on the whole, more regular. The size of the grains is closely related to the shape and surface condition, one quality merging into another and requiring common consideration in the case of substances which require handling in practice.

The moisture content produces a retardation of the flow. The influence with increasing fineness and decreasing density becomes greater. The moisture in material which is positively dampened can alter the rate of flow many-fold, producing results out of all semblance to uniformity. As the material becomes progressively drier, the velocity of flow becomes greater and more uniform.

Angularity of the particles causes a diminution of velocity. The effect is less marked with fine material and with large orifices.

The uniformity of size of the grains is of influence upon the velocity. The velocity of a mixture of materials, with respect to the weight, approximates and slightly exceeds the mean of the velocities of the two sizes flowing separately. Thus the time occupied in the discharge of a given weight of material of mixed sizes is slightly less than that which would be required for the discharge of each sized constituent separately. This is shown in Diagram II.

The material of which the orifice is constructed is shown to modify the velocity to a small extent. Results with ¼-inch orifices are given in Table IV.

The specific gravity of the flowing material is without relatively appreciable influence upon the velocity of flow under practical conditions. This is shown in Table III.

The sand-head exerts a barely appreciable influence upon the velocity of flow. The influence is in the direction of a decreasing velocity with increasing head. With materials capable of becoming compressed or compacted, the retarding effect of the head becomes more pronounced. A consideration of the sand-head must thus include not only the height of the column and the specific gravity of the material, but the impact in gathering above the orifice, the dampness, coherence, and the angularity.

The contour at the surface of the material above the orifice exerts a minute influence upon the velocity. Thus when the surface is allowed to sink directly above the orifice, so as to

form a pit, there is a slight increase in flow perceptible beyond that observed when the surface is level at the height corresponding to the bottom of the pit.

The shape of the receptacle supplying an orifice has but slight influence upon the velocity of flow where the bottom is flat around the orifice and the vertical column of material above the orifice remains unobstructed.

The effect of taper in orifices is an increase in flow where the enlarged opening of the orifice is presented to the descending material.

The length of discharge-orifices, or the thickness of the plate through which orifices are cut, is of scarcely appreciable effect as examined within the range of one inch.

The size of an orifice at the minimum required for an assured continuous flow must liberally exceed that found suitable for short intervals, to provide for the variability in quality of usual sands and the chance arrangement of particles in obstruction. The diameter of round orifices suitable for the steady flow of the sand materials tested ranges from five to twenty times the diameter of the particles, according with the size and quality of the material.

The horizontal, cross-sectional shape of the vertically discharging orifice influences the velocity of flow. The velocity is highest among the discharge-orifices tested having the greater ratio of area to periphery.

The area or size of the orifice affects the velocity. Thus the discharge is governed both by the area over which the given velocity is effective and by the velocity resulting from this area. It is seen in Diagram III that the velocity decreases with the decreasing diameter of the orifice, the curve showing a rapid decline near the limiting size of the orifice where the flow becomes irregular.

The differences in the surface condition of the grains, with the influence which this has upon the cohesion and the frictional coefficient, produce an important effect upon the velocity of flow. The content in moisture, the composition of the material, the hygroscopic properties, the angularity, and the uniformity of size are best judged, for purposes in practice, by the evident general quality of the material as a whole. In the case of lead shot, a material in which the influence of angularity of the

grains is eliminated, a variation of 20 per cent. or more in the velocity results from the alteration of the surface with substances imparting a high and a low coefficient of friction.

An approximate constant to express the flow in terms of the orifice area, or the coarseness of material, can be used to gain a general idea of the discharge capacity of an orifice for a given material. Under the conditions of apportionment of sand materials by orifices in practice, prediction must be considered widely approximate. Results, moreover, are liable to marked deviation from changing quality of the material. In such application, differences in the specific gravity and the sand-head are of relatively small importance. The flow is seen to be actuated by the force acting upon the material distant but few diameters of the orifice from the orifice, and is thus affected only by the condition there existing. There is little serviceable analogy between the flow of fluid substances and of sand composed of solid grains.

An expression giving an idea of the flow to be expected would be sought for certain purposes from the trend of the curves. For such approximation, in which an accuracy of some 20 to 50 per cent. is obtained, based upon the size of the round orifice and the coarseness of the material, the following formula may be suggested:

$$V = k\frac{d - cm}{\sqrt{d}}.$$

Here d is the diameter of the orifice in inches, m is the diameter of the particles in inches, V is the velocity of flow in feet per second, and k and c are constants to which are assigned respectively, in approximation, the numerical values 1 and 2.

The weight of sand discharged during each minute is correspondingly shown in the same degree of approximation by substituting the above value of V for the value v in equation (4), for round orifices, as given under *The Rate of Discharge*. From this the following equation is derived:

$$W = 20.43\, s\sqrt{d^3}\,(d - 2m).$$

Here W is the weight of sand discharged in avoirdupois pounds per minute, s is the specific gravity of the sand in the

dry, loosely aggregated state, *d* is the diameter of the round orifice in inches, and *m* the diameter of the grains in inches.

An outline of the conclusions to be drawn from the tests described would be: (1) The increase in the velocity of flow with the increase in the diameter of the orifice; (2) the increase in the velocity of flow with the decrease in the diameter of the particles until the size of relatively fine material is reached; (3) the comparative unimportance of the variation in specific gravity of materials; (4) the relatively small influence of the variations in head; (5) the relatively small influence of the shape of the supplying reservoir; and (6) the influence of dampness and compacting qualities of the material, most marked in the fine sizes.

Cementation with Mixed Carburizing Agents. A. PORTEVIN. (*Mem. Soc. Ing. Civils de France*, lxvi, 347.)—This describes experiments on a practical scale of cementation with mixed agents,—*i.e.*, with a layer of wood charcoal of considerable thickness through which a current of carbon dioxide is passed at the temperature of cementation. The advantages of this method of cementation are described in detail.

Methyl Alcohol as a By-product in the Manufacture of Wood Cellulose. H. BERGSTRÖM. (*Papierfabrikant*, x, 697.)—Since 1908 the Billingsfors mill has been recovering methyl alcohol as a by-product from the digestion of wood by the sulphate process. In the manufacture of easy bleaching pulp, about 13 kilos. of methyl alcohol are produced per 1000 kilos. of cellulose. About 5 kilos. of this per 1000 are collected by condensing the vapors discharged at between 10 and 4 atmospheres from the digesters. This spirit is purer than ordinary wood spirit and contains 0.5 per cent. of acetone. The cost of recovering methyl alcohol amounts to 10 oere per kilo., or 12 cents per pound of absolute alcohol, and its value is 45 oere, or 54 cents per pound. More crude spirit may be obtained by condensing the vapors discharged below 4 atmospheres and those formed during evaporation of the lyes, and the refining of the raw spirit is profitable. This year five sulphate pulp factories are recovering methyl alcohol. Pine wood and spruce wood yield about the same quantity of spirit. In the digestion of wood by the Ritter-Kellner sulphite process, from 8 to 10 kilos. of methyl alcohol are formed per ton of easy bleaching cellulose, about 3 kilos. being condensed in the "gassing-off" process. If the waste lyes remaining in the digester be then distilled in a continuous column apparatus, a distillate is obtained containing methyl alcohol, acetaldehyde, acetone, oils, sulphurous acid partly combined, and small quantities of formic and acetic acids.

NOTES FROM THE U. S. BUREAU OF STANDARDS.*

ABSORPTION CONSTANTS OF QUARTZ.

Paper by W. W. Coblentz.

An accurate knowledge of the transmission of quartz, in the infra-red, is essential in order to determine spectral energy curves. Quartz has a much larger dispersion than fluorite. Unfortunately, unlike fluorite, the absorption in quartz becomes quite marked at 2μ and is practically complete beyond 3μ. However, for the spectral region from the deep ultraviolet to 1.7μ in the infra-red, quartz has the remarkable property of complete transparency for the thicknesses (3 cm.) which are ordinarily used in optical investigations. This is illustrated in the present research, where it is shown that after eliminating the losses for reflection at the interface, quartz-air, the transmission is practically complete.

In this investigation an especially prepared cylinder of clear quartz, 50 mm. in diameter and 29.925 mm. in thickness, cut perpendicular to the optic axis was used. The faces were plane to a fraction of a wave-length of light, and they were parallel to within 1′. The source of energy was a seasoned Nernst glower, operated on a storage battery. The rays from the glower were made parallel by means of a 50 cm. focal length silvered mirror, and from thence passed to a second mirror, 90 cm. focal length, which brought the rays to focus upon the spectrometer slit. A blackened diaphragm having an opening of about 3 by 3.5 cm. was placed in the path of parallel rays. The quartz cylinder was mounted upon a suitable stage, sliding back and forth, close to and in the rear (*i.e.*, between the diaphragm and the second mirror) of the diaphragm. The ratio of the galvanometer deflection observed when the quartz plate was over the opening in the diaphragm, to the deflection caused by the rays passing through the diaphragm without obstruction by the quartz, gave the transmission, which, of course, includes the losses by reflection from the two surfaces. Atmospheric disturbances were unusually small,

*Communicated by the Bureau.

so that the galvanometer could be read to 0.1 mm., thus producing an accuracy of several parts in one thousand instead of a few parts in one hundred, which is the usual record of radiometric work.

The true transmission of quartz is obtained by applying the well-known Fresnel formula for vitreous reflection. The radiations contributed by two reflections $(1+\gamma^2)$ within the quartz plate are negligible in most work. If there were no errors of observation and no scattering of light, the values should be $T_0 = 1$. This is true to about two parts in 1000 for the region of transparency from 0.8μ to 1.8μ. The second column of Table I gives

TABLE I.

TRANSMISSION OF QUARTZ.

λ	T'_0 $l=29.925$ mm.	T'_0 $l=27.915$ mm.	Absorption index. K—Mean value of two samples.
0.0005893	.99600	.99578	0.000,000,007,803
.0008820	.99970	.99545	0.000,000,009,153
.0011971	1.00223	.....	0.000,000,001,808
.0016132	1.00000	1.0000	0.000,000,009,567
.0017835	.99984	.99986	0.000,000,011,06
.0019518	.99665	.99768	0.000,000,021,57
.0021128	.99292	.99478	0.000,000,036,13
.0022654	.98620	.98796	0.000,000,066,96
.0024098	.97782	.97948	0.000,000,108,98
.0025458	.95020	.95552	0.000,000,238,99
.0026120	.....	.93994	0.000,000,322,64
.0026757	.91954	.92715	0.000,000,405,34
.0027392	.....	.84458	0.000,000,893,69
.0028010	.54944	.57891	0.000,002,949,58
.0029213	.099696	.08135	0.000,012,939,7
.0030373	.....	.15496	0.000,010,793,4

the transmission T'_0 on the assumption that there is perfect transmission up to and at 1.6132μ. The deviations from $T_0 = 1$ are then found to be far smaller than the average experimental errors which usually enter into such work.

The absorption index (extinction coefficient) κ is computed from the equation $A = l - e^{-al}$, where $a = 4\frac{\pi\kappa}{\lambda}$. Here the thickness, l, of the plate and the wave-length are in millimetres. The data are given in the last column of Table I. The absorption band of quartz occurs at 2.95μ.

The factors for eliminating the absorption in a wedge of quartz are determined from the equation

$$\frac{I_0}{I} = \frac{\log (1-A)^{B/l}}{[(1-A)^{B/l}-1]\log \epsilon}$$

In these equations A is the absorption $(1 - T_0)$ observed in the quartz plate and l is its thickness (29.925 mm.); B is the thickness of the back of the prism (*i.e.*, the width of the face, 52 mm., which is opposite the refracting angle), and h is the vertical height of the refracting edge from the back of the prism. The observed intensity (in galvanometer deflections) is I; and I_0 is the true intensity of the radiations emanating from the source. A further increase in the value of I_0 is, of course, necessary for loss by reflection, r, from the prism faces and for variation of reflection, γ^2, with angle of incidence.

Table II gives the factors to be used in eliminating this absorption in a quartz prism the back face of which is 50 to 52 mm. in thickness. From this table it will be found that, for example, at 2.70μ the observed intensity must be increased by 8.8 per cent. in order to correct for the loss by absorption in the prism.

TABLE II.

TRANSMISSION—QUARTZ.

Factors for eliminating absorption in a quartz prism having a base (back face) of 50 to 52 mm. width.

λ	Factor
1.8	1.0000
1.85	1.0010
1.90	1.0019
1.95	1.0028
2.00	1.0038
2.05	1.0050
2.10	1.0062
2.15	1.0076
2.20	1.0091
2.25	1.0108
2.30	1.0132
2.35	1.0165
2.40	1.0205
2.45	1.0262
2.50	1.0335
2.55	1.0430
2.60	1.0550
2.65	1.0690
2.70	1.0880

Lack of Dock Accommodation. ANON. (*Amer. Mach.*, xxxix, No. 24, 996.)—The increase in the size of modern transatlantic liners has called attention to the lack of suitable dock accommodation, but this is being remedied on this side of the ocean. Both Canada and this country are beginning to feel their responsibilities, and dry docks to take the largest ships will soon be found on the Atlantic seaboard. The Canadian Government is planning to build at Levis, on the St. Lawrence, a dry dock of the following dimensions: length, 1160 feet; width of entrance, 120 feet; depth of sill at ordinary high water, 40 feet. It will be the largest in existence and will be divided into two sections, 660 and 500 feet long respectively. Boston is shortly to have two dry docks capable of receiving the largest boats, though these will not be quite so large as the Canadian docks. They are to cost approximately $3,000,000, and the Cunard, International Mercantile Marine, and Hamburg-American lines are to subscribe $50,000 a year for 20 years for their use.

Nickel as Catalyst. J. B. SENDERENS and J. ABOULENC. (*Bull. Soc. Chim.*, xi, 641.)—The temperature at which nickel oxide is reduced by hydrogen depends on the mode of preparation and treatment of the oxide used; there is also a considerable difference between the temperature at which reduction commences and that at which it is complete. Complete reduction is not effected below 300° C., but the mixture of metal and oxide thus obtained is more active than the metal prepared by total reduction at a higher temperature; the activity of reduced nickel being diminished by heating to a comparatively high temperature, although at the same time its catalytic properties become more permanent. Pyrophoric nickel, when heated in the air, furnishes an oxide which is reducible at a comparatively low temperature, and reduced nickel of impaired activity may be restored by oxidizing it and again reducing.

A New Alloy—Argental. ANON. (*Amer. Mach.*, xxxix, No. 24, 1002.)—The inventor of the "McAdamite" alloy has produced this new alloy of silver and aluminum, named Argental. It was produced as a substitute for silver, and is claimed to be superior to silver for many industrial uses. It can be cast, rolled, spun, drawn into wire, and takes a good polish, and is stronger than either silver or aluminum. It resembles silver, is not affected by nitric acid, and does not tarnish in air. As its specific gravity is only one-third that of silver, it may be used for the manufacture of tableware specialties and the like.

Quality of Steel. ANON. (*Amer. Mach.*, xxxvi, 26, 1018.)—The rapid development in the quality of steel must be credited to a great extent to the automobile and the aëroplane. Wire for aëroplane stays or guys is made from 0.025 to 0.102 inch diameter, with a tensile strength of 350,000 pounds per square inch.

THE FRANKLIN INSTITUTE

(Proceedings of the Stated Meeting held Wednesday, March 18, 1914.)

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, March 18, 1914.

PRESIDENT WALTON CLARK *in the Chair.*

Additions to membership since last report, 6.

Dr. George A. Hoadley, on behalf of the Committee on Science and the Arts, introduced Mr. George W. Loggie, treasurer of the Kinkead Manufacturing Company, Boston, Massachusetts, to whom had been awarded the Longstreth Medal of Merit for their apparatus for aligning and levelling shafting. The chairman then presented the medal to Mr. Loggie.

After the transaction of the above business a joint meeting was held with the Philadelphia Section of the American Institute of Electrical Engineers, President Clark and Chairman Cheyney presiding jointly.

It was announced that because of death in his family Dr. Edwin F. Northrup, who had been scheduled to speak on "The Problem of Electrical Conduction," found it impossible to be present.

Mr. H. A. Hornor, Electrical Engineer of the New York Shipbuilding Company, presented an interesting communication on "The Marine Applications of Electricity." The many and varied uses of electricity on board ship were fully described, including its applications in signalling to and from various parts of a vessel, as an adjunct in gunnery for range finding and other purposes, for lighting, heating, baking, and for communication between vessels and land. The subject was illustrated by lantern slides.

After a vote of thanks to the speaker, the meeting adjourned.

R. B. OWENS,
Secretary.

COMMITTEE ON SCIENCE AND THE ARTS.

(Abstract of Proceedings of the Stated Meeting held Wednesday, March 4, 1914.)

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, March 4, 1914.

MR. GEORGE R. HENDERSON *in the Chair.*

The following report was presented for first reading:

No. 2596.—Hirsch's Electric Safety Lamp.

The following report was presented for reconsideration:

No. 2530.—Stumpf's Una-Flow Steam Engine. Edward Longstreth Medal of Merit. Adopted.

The following resolution, expressing the regrets of the committee on the retirement of Prof. Lewis M. Haupt, was unanimously adopted:

"The Committee on Science and the Arts of The Franklin Institute, in view of the retirement of Prof. Lewis M. Haupt from active participation in its work, unanimously resolves that the following appreciation shall be entered on the minutes of the committee and published in the JOURNAL of the Institute:

"The committee notes that Professor Haupt's membership in this body has extended almost continuously through more than thirty years (from 1883 to the present time), and makes record that throughout this period his collaboration, not only as an acknowledged authority in water and land transportation, in harbor improvements and in the broad domain of engineering generally, but also as a scientific publicist and economist, has been of the utmost value to the cause for the promotion of which this committee is organized.

"The committee has come to recognize Professor Haupt as a veteran scientist whose ripened judgment has been instructive and whose genial personality has been an inspiration to all his co-workers, and greatly regrets that his formal and active coöperation has now been withdrawn. On its own behalf and for the Institute, the committee extends to Professor Haupt a thankful acknowledgment of his many years of valuable service."

R. B. OWENS,
Secretary.

PRESENTATION OF THE EDWARD LONGSTRETH MEDAL OF MERIT TO KINKEAD MANUFACTURING COMPANY.

The Edward Longstreth Medal of Merit, awarded to Kinkead Manufacturing Company for their apparatus for aligning and levelling shafting, was presented to Mr. George W. Loggie, Treasurer of the Company, at the Stated Meeting of the Institute on Wednesday evening, March 18.

Dr. George A. Hoadley referred to the recommendation embodied in the report of the Committee on Science and the Arts, that this Medal be awarded the Company for their device in consideration of its novelty, simplicity, and efficiency. He then presented Mr. Loggie to the President, by whom he was given the Medal.

SECTIONS.

Section of Physics and Chemistry.—A meeting of the section was held in the Hall of the Institute on Wednesday evening, February 11, at eight o'clock.

Mr. Louis E. Levy occupied the chair.

The minutes of the previous meeting were approved.

Oswald Schreiner, Ph.D., of the Bureau of Soils, U. S. Department of Agriculture, Washington, D. C., delivered an illustrated lecture on "The Biochemistry of Soil Fertility," in which he described the soil fertility investigations of that Bureau.

A description was given of the gradual chemical decomposition of animal and vegetable matter in the soil with the formation of a great number of organic compounds, some toxic to plant life, others exerting a highly favorable influence on plant growth. The methods of isolation of these compounds from the soil, and of testing their action, singly, in combination with each other, and with inorganic fertilizers, upon plants in the laboratory and in field experiments, were discussed. The relation of the results obtained to scientific agriculture was shown.

The paper was discussed at great length, a vote of thanks was extended to Dr. Schreiner, and the meeting adjourned.

JOSEPH S. HEPBURN,
Secretary.

Mechanical and Engineering Section.—A meeting of the section was held in the Hall of the Institute on Thursday evening, February 26, at eight o'clock.

Dr. Walton Clark occupied the chair.

The minutes of the previous meeting were approved as published.

The Chairman introduced Prof. M. E. Cooley, D.Eng., LL.D., Dean of the Department of Engineering, University of Michigan, Ann Arbor, Mich., who delivered a lecture on "The Valuation of Public Utility Properties."

The speaker emphasized the necessity of a correct knowledge on the part of the public of the fundamentals of public utilities. He said that the fullest coöperation should exist between public utility commissions of the different States, municipalities, and the Federal Government, in framing legislation and in the conduct of investigations of the relations of public utilities to the public. He outlined the many expenses entailed in promoting a public utility, which he said were but rarely considered by the public.

After discussion by members present, the thanks of the meeting were extended the speaker.

Adjourned.

WILLIAM E. BULLOCK,
Acting Secretary.

Section of Physics and Chemistry.—A meeting of the section was held in the Hall of the Institute on Thursday, March 5, 1914, at 8 o'clock P.M., with Mr. E. H. Sanborn in the chair. The minutes of the previous meeting were read and approved. L. C. Jones Ph.D., of the Solvay Process Company, Syracuse, N. Y., delivered an address entitled "By-Products of Coal," in the course of which he discussed the geo-chemistry of the formation of coal deposits and described certain new coal fields. The physical and chemical changes undergone by various species of coal on heating were described, as was the influence of the temperature and the pressure on the yield of gaseous products, ammonia, forrocyanide, and benzol hydrocarbons. The lecture was illustrated by means of lantern slides and by specimens of coals before and after heating. The paper was discussed and, on motion of Dr. Walton Clark, a vote of thanks was extended to the speaker. The meeting then adjourned.

JOSEPH S. HEPBURN,
Secretary.

MEMBERSHIP NOTES.

Elections to Membership.

(Stated Meeting, Board of Managers, March 11, 1914.)

RESIDENT.

MR. J. STUART FREEMAN, 1429 Chestnut Street, Philadelphia.
DR. CHARLES S. HOLLANDER, 40 North Fourth Street, Philadelphia.
MR. JOSEPH M. JAMESON, Girard College, Philadelphia.
MR. CHARLES W. THOMAS, Silica Stone Works, Frazer, Pennsylvania.

NON-RESIDENT.

MR. HERBERT A. BURSON, Canadian Crocker-Wheeler Company, St. Catherines, Ontario, Canada.
MR. MALCOLM ELLIS, Ellis Adding Typewriter Company, Newark, New Jersey.

Changes of Address.

MR. FRANCIS H. ADLER, 3400 Walnut Street, Philadelphia.
MR. FRANCIS T. CHAMBERS, Esquire, 712 Walnut Street, Philadelphia.
MR. GEORGE R. HALL, Hotel Grand, 31st and Broadway, New York City, New York.
MR. T. CHALKLEY HATTON, City Hall, Milwaukee, Wisconsin.
MR. WILLIAM R. HUTTINGER, 58 West Stratford Avenue, Lansdowne, Pennsylvania.

NECROLOGY.

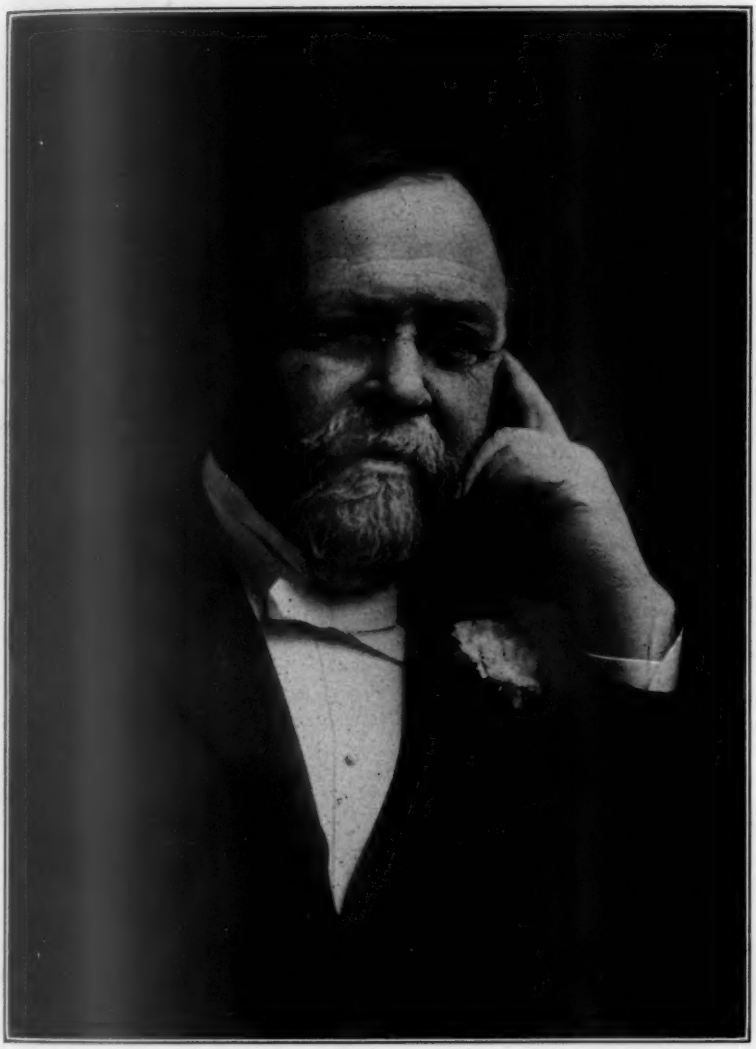
Dr. Edwin James Houston was born at Alexandria, Va., in 1847. He was educated at the Central High School, Philadelphia, and was graduated Bachelor of Arts in 1864; he received his Master's degree from the school later, and subsequently the honorary degree of Doctor of Philosophy from Princeton University.

For twenty-six years Dr. Houston was a member of the faculty of the Central High School, occupying the chair of Physical Geography and Chemistry. Later he became associated with Dr. A. E. Kennelly under the firm name Houston and Kennelly, consulting engineers.

He was perhaps best known as one of the inventors of the Thomson-Houston system of arc lighting and as a writer of many books on electrical subjects.

Dr. Houston was elected to life membership in The Franklin Institute in 1868. He was a member of a number of committees, including special electrical committees and committees on lectures and meetings. He was chief electrician of the International Electrical Exhibition held in Philadelphia in 1884 under the auspices of the Institute.

He was Emeritus Professor of Physics of The Franklin Institute, a member of the 1884 U. S. Electrical Commission, the American Philosophical Society, the American Institute of Mining Engineers, and was twice President of the American Institute of Electrical Engineers.



EDWIN JAMES HOUSTON
1847–1913

George Westinghouse was born at Central Bridge, N. Y., in 1846. He attended the public high schools at Schenectady, and at the age of seventeen enlisted in the Union Army. In 1864 he was appointed Third Assistant Engineer, U. S. Navy, and was honorably discharged in the following year. He then entered Union College, where he remained until the close of his sophomore year. He had early exhibited an inventive capacity, having at the age of fifteen developed a rotary engine. In 1865 he invented a device for replacing derailed railroad cars upon their tracks, and three years later he patented his first invention of the air-brake.

The Westinghouse Air Brake Company was formed in July, 1870, and in the same year Mr. Westinghouse went to England to introduce the air-brake there. He spent seven years in that country between 1871 and 1882, and succeeded in overcoming the difficulties incident to the application of his invention to European railroad practice. In the meantime, he invented the "automatic" feature of the brake, which removed the danger from the parting of trains on steep grades, accomplished by the incorporation of the "triple valve." The automatic and quick action brakes are regarded by experts as surpassing the original brake in ingenuity, and, in the present-day air-brake practice, these inventions are utilized as essential embodiments.

In 1880 Mr. Westinghouse became interested in the operation of railway signals and switches by compressed air, and the system later patented by him was successfully introduced at many of the largest depots in this country.

The Westinghouse Electric Company was formed in 1886 as a result of Mr. Westinghouse's interest in the manufacture of electric lamps and lighting apparatus; the business of this corporation rapidly developed, and it absorbed other properties and was reorganized into the Westinghouse Electric and Manufacturing Company in 1891, the concern now employing over twenty-two thousand people. Mr. Westinghouse secured for this company the contract for the electrical equipment of the World's Fair in 1892, and for the generators at Niagara Falls in the following year.

The question of the steam turbine and its applications was investigated by Mr. Westinghouse, and he secured the patent rights of Chas. A. Parsons, of England, in 1897–98. This development of a new prime mover soon led the inventor to consider the use of the turbine as a prime mover for ships, and Mr. Westinghouse developed and brought out one of the most ingenious devices of modern mechanical engineering—the gear for reducing the inherently high speed of a turbine to the slow speed of a ship propeller or direct current dynamo. He accomplished this work in collaboration with the late Admiral Geo. W. Melville, U. S. N., and John H. MacAlpine. Within the last few years he also occupied himself with the development of an air spring for automobiles and motor trucks, which rapidly came into favor.

Mr. Westinghouse rendered an invaluable service to electrical development when, in spite of much opposition, he remained steadfast in his belief that the alternating current system of high-tension transmission would make distant electrical distribution possible.

A struggle almost identical with that of the earlier fight for alternating-

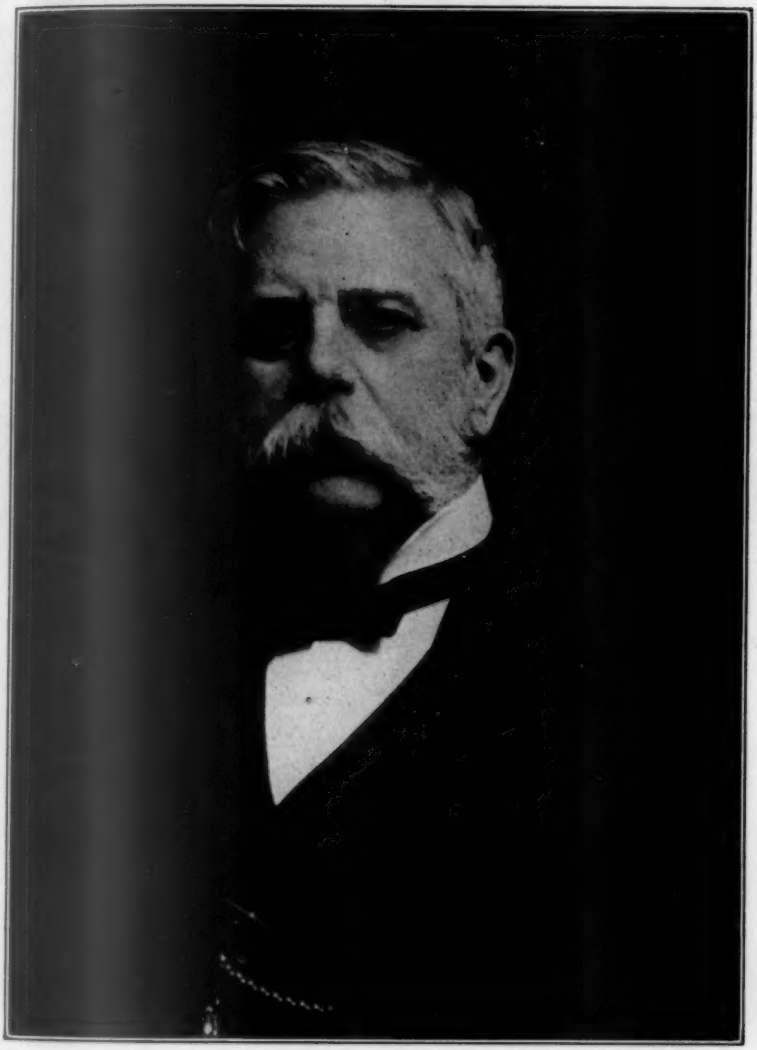
current transmission was the recent introduction of alternating-current traction by means of the single-phase motor, which the Westinghouse Electric and Manufacturing Company has now brought into reality in the case of a number of traction lines, railroad terminals and tunnels. In spite of the same competition, Mr. Westinghouse made a step in electric railway practice which the electrical world was, in like manner, quick to follow.

Originating with one of the most important inventions connected with railways, the various Westinghouse industries have grown and have been largely identified with railway progress, and it is interesting to note that this progress has represented increased security of life, increased capacity of the railway, and reduced cost of operation.

As with his first invention, the air-brake, the different apparatus has been developed to answer actual needs, in some cases acknowledged generally, and in others foreseen by him with remarkable precision. When the apparatus had passed the experimental state and was ready for commercial exploitations, he established factories which are themselves models, and which show the same anticipation of future development. Not only are the buildings handsome and well equipped with the best tools, but the comfort of the employees has been considered in every respect. It is noteworthy that the fifty-four-hour week was started in the Air Brake Works in 1869, and has been adopted in all the other plants as they have been established.

Mr. Westinghouse received many honorable distinctions for his achievements and in recognition of the services he rendered the various branches of engineering. His alma mater, Union College of Schenectady, conferred upon him the degree of Doctor of Philosophy in 1890. He was decorated with the order of the Legion of Honor, with the order of the Royal Crown of Italy, and with the order of Leopold of Belgium. He was the second recipient of the John Fritz medal. He received the honorary degree of Doctor of Engineering from the Koenigliche Technische Hochschule of Berlin, Germany, in 1906. He was an honorary member of the American Society of Mechanical Engineers, of which body he was president in 1910. He was one of the two honorary members of the American Association for the Advancement of Science. He was an honorary member of the National Electric Light Association of America. He was awarded the John Scott Medal and Premium by the City of Philadelphia, acting on the recommendation of The Franklin Institute of the State of Pennsylvania for his inventions of the air-brake in 1874. He received the Edison gold medal for meritorious achievements in the alternating-current system of electrical distribution. In December, 1913, he was presented, in New York City, with the Grashof Medal awarded him by the Verein Deutscher Ingenieure, which society recognized him as the greatest American engineer.

Mr. Westinghouse was connected with a large number of industries both at home and abroad. He was President and Director of Westinghouse Air Brake Co.; Westinghouse Machine Co.; Nernst Lamp Company; The Union Switch & Signal Co.; Société Anonyme Westinghouse, Paris; Cooper Hewitt Electric Co.; Pittsburgh Meter Co.; Société Italiane Westinghouse, Italy; The East Pittsburgh Improvement Co.; the Westinghouse Brake Co., Ltd., London; Westinghouse Cooper Hewitt Company, London;



GEORGE WESTINGHOUSE, JR.
1846–1914

Westinghouse Friction Draft Gear Co.; Westinghouse Metal Filament Lamp Co., Ltd., London. He was also Chairman of the Board of Directors of Westinghouse Electric Co., Ltd., London; and Director, Westinghouse Electric & Manufacturing Co., Pittsburgh, Pa.; the Traction & Power Securities Co.; Westinghouse Metallfaden Glühlampenfabrik, Vienna. He became a life member of the Institute on July 3, 1873.

Mr. George Thomson was born in Philadelphia November 25, 1841. He was educated in the schools of his native city and about 1861 with Amos Westcott founded the firm of Westcott & Thomson, who were among the first in Philadelphia to apply electrotyping to commercial purposes. Mr. Thomson took an active interest in politics and was a member of numerous fraternal associations. He died January 28, 1914.

Mr. Charles H. Cramp, Beach and Ball Streets, Philadelphia.
Mr. H. Van Meerten, Buitenzorg, Java.
Dr. Thomas Wistar, East Penn Street, Philadelphia.

LIBRARY NOTES.

Purchases.

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FLEMING, A. P. M.—Insulation and Design of Electrical Windings. 1913.
HADDON, I. J., and H.—Practical Treatise for Boiler Makers. 1913.
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BOOK NOTICES.

INDUSTRIAL ORGANIC ANALYSIS. By Paul S. Arup. Published by P. Blakiston's Son & Company, Philadelphia. 340 pages, 18 x 12 cm. Price, $2.25.

The purpose of this little manual is to supplement the purely scientific training of the chemical student by some training in practical methods. The

subjects handled are fuels, coal tar, oils and fats, soap, petroleum, and food products. Each chapter ends with an excellent bibliography. In most cases the author has wisely adopted the policy of giving only one method for each determination. A multiplicity of methods merely bewilders the beginner, since he has not as yet had the experience necessary to make an intelligent choice. The author of his text-book should do the selecting.

In the present book the methods are well chosen and the descriptions, while concise, are sufficiently full and exact. There is an excellent index.

ROBERT H. BRADBURY.

QUANTITATIVE ANALYSIS. By Frank Clowes and J. Bernard Coleman. Tenth edition. Published by P. Blakiston's Son & Company, Philadelphia. 577 pages, 22 x 14 cm. Price, $3.50.

The ninth edition of this standard text was reviewed in this JOURNAL about two years ago. The size of the book remains almost unchanged from the ninth edition, only twelve pages having been added. Nevertheless, some interesting new matter appears. Among the more noteworthy additions are methods for the analysis of commercial aluminum and bauxite, for the estimation of titanium in iron ores, for the determination of phosphorus and manganese in iron and steel, of moisture in coal, of foreign fats in butter, and a description of a new drying oven. This new material is collected into an appendix.

In the analysis of aluminum the fact that the commercial metal invariably contains *gallium* is not mentioned. However, the percentage of gallium is very small, and its determination would hardly be a task for the beginner.

The new method for phosphorus consists in dissolving the yellow phosphomolybdate precipitate in ammonia, acidifying with hydrochloric acid, and precipitating with a solution of lead acetate. The lead molybdate is ignited and weighed and the phosphorus calculated. In other words, the method is merely an application to phosphorus of Chatard's method for determination of molybdic acid.

The student who works the method from the description on page 550 would in all probability ignite his lead molybdate with the filter in a covered platinum crucible. Probably the author intends him to use a Gooch crucible, but there is nothing to indicate the fact. The reviewer has no experience of the method, but he confesses to cherishing considerable scepticism as to whether it possesses any advantages over the method at present in use for the estimation of phosphorus.

This is probably the best manual to put into the hands of the student beginning quantitative work. The usefulness of the book is greatly increased by an elaborate system of cross-references.

ROBERT H. BRADBURY.

ALLEN'S COMMERCIAL ORGANIC ANALYSIS. Fourth edition, vol. viii. Edited by W. A. Davis and S. S. Sadtler. Published by P. Blakiston's Son & Company, Philadelphia. 696 pages, 23 x 14.5 cm. Price, $5.

The fourth edition of this standard work is now complete. The chief

subjects treated in the eighth and final volume are Enzymes (Armstrong), Proteins (Schryver), Proteins of Plants (Armstrong), Milk (Leffmann), Meat (Richardson), Albuminoids (Alexander), Fibroids and Artificial Silk (Dreaper).

ROBERT H. BRADBURY.

BLOXAM'S CHEMISTRY. Tenth edition, rewritten and revised by Arthur G. Bloxam and S. Judd Lewis. Published by P. Blakiston's Son & Company, Philadelphia. 878 pages, 24 x 15 cm. Price, $5.50.

When the first edition of Bloxam was issued, in 1867, it gave, in little more than six hundred pages, a compendious account of the chemical science of the time. At present, just about half a century later, the task of adequately treating all phases of the subject, technical and scientific, organic and inorganic, in a single volume wears a very different aspect. It is somewhat difficult to see what advantages a single encyclopædic work possesses, compared with several smaller specialized books covering the same ground. Nevertheless, the marked success of the two recent volumes by Ettore Molinari indicates that there is a considerable demand for comprehensive treatment of this kind.

The authors of the present book are to be congratulated on having performed a laborious piece of work in a very creditable way. The book presents an enormous mass of information on all branches of chemistry. It has been revised and modernized with great care, and everything which may fairly be supposed to fall in its scope is to be found in it. The index—a most important feature in a comprehensive volume of this kind—is unusually complete, covering more than fifty pages in double column.

ROBERT H. BRADBURY.

DIE ENTDECKUNG DES RADIUMS. Von Mme. P. Curie. Octavo, 28 pages, with 5 illustrations. Leipzig: Akademische Verlagsgesellschaft m. b. H. Price, 1.50 marks.

This is the authorized German edition of the address delivered by the illustrious discoverer on receiving the Nobel Prize for Chemistry in 1911. It narrates in charmingly simple and clear language the story of the discovery and investigation of the radio-active substances. While of necessity this account is largely concerned with the results of her work on radium and polonium, for which the prize was awarded her, the author, in a most delightful spirit of fairness and generosity, accords due credit to the other great investigators in the field of radio-activity. Particularly pleasing in this respect are her references to the achievements of Henri Becquerel and Ernest Rutherford, and to the part which her late and lamented husband, Pierre Curie, has had in the discovery of radium and polonium. It is impossible, after reading this pamphlet, to conceive of a more deserving tribute to a great scientist than the award of the Nobel Prize in chemistry to Mme. Pierre Curie.

H. F. KELLER.

LETZTE GEDANKEN. Von Henri Poincaré. Octavo, 261 pages. Leipzig: Akademische Verlagsgesellschaft, m. b. H., 1913.

As the title indicates, this is a posthumous publication from the pen of the great mathematician and philosopher. It contains nine essays and addresses on a great variety of topics, but in every instance discussing with the author's well-known breadth of vision and lucidity of presentation some scientific or ethical problem of fundamental importance. A mere glance at the headings suffices to indicate the character of this remarkable book; they are as follows: Are the Laws of Nature Invariable?; Space and Time; Why Space has Three Dimensions; The Logic of the Infinite; Mathematics and Logic; The Hypothesis of Quanta; Matter and Universal Ether; Morals and Science; and The Universality of Ethics.

In the warmly sympathetic preface which Ostwald has written for this excellent German translation of Poincaré's book he points out that the author is a typically modern investigator "who cannot acquire knowledge or occupy himself with new conceptions without engaging in creative labor in the new field thus opened up to him."

H. F. KELLER.

DER WERDEGANG EINER WISSENSCHAFT: Sieben gemeinverständliche Vorträge aus der Geschichte der Chemie von William Ostwald. Second edition. Leipzig: Akademische Verlagsgesellschaft m. b. H. Small 8vo, 308 pages and index. Price, 6.60 marks.

This is a compact summary of salient features in the history of chemistry, written so as to be useful to those not fully trained in the science. It suggests somewhat Würtz's "History of the Atomic Theory," but does not show the chauvinism of that work, which boldly and unjustly starts off with the declaration "Chemistry is a French science." Ostwald's book is in part a report of his lectures about eight years ago at the Massachusetts Institute of Technology and Columbia University, but, as might be expected, material alterations and additions have been made in reducing these to the printed form. The seven subjects are: The Elements; Combining Weights and Atoms; The Laws of Gases and the Molecular Theory; Isomerism and Structure; Electrochemistry; Affinity; Chemical Dynamics.

It is unnecessary to say that we have here presented in attractive literary form an accurate synopsis of these several important phases of the development of chemistry. The first lecture devotes some space to the very earliest history, taking, as usual, Thales as the first who treated of the manifold phenomena of nature as explicable on material principles. He regarded water as the primordial material—at least taught that all existing matter is derived from the transformation of water. Ostwald points out that in Thales's philosophy are to be found two principles that are still dominant in modern science: The doctrine that the present condition of matter is the result of change from a former condition—things have not always been as they are—and that the manifold forms of matter are referable to a limited number of original substances. The first doctrine dominates biology; the second the abiologic sciences, chemistry and physics.

By many scientists Ostwald is admired, not only for his work in research and his capacity for presenting the results of his studies in a popular form, as well as in the technical language of highly-developed science, but also

for his aggressive liberalism, and his fearless association with those who are appealing for a scientific interpretation of life. The redeeming quality of Saxon humor is not lacking, as the following quotation will show:

"*Liebig, der sich durch seine in der Dachkammer der Apotheke, in der er Lehrling war, ausgefürthen Arbeiten über dass Knallquecksilber glücklich aus der Apotheke heraus, aber in die Aufmerksamkeit einflussreicher Personen hineinexplodiert hatte, war nach Paris gegangen.*" Then follows an account of the independent discovery by Liebig and Wöhler of the isomeric cyanic acids, the intervention of Berzelius with his skilful generalization, and the establishment of a lifelong friendship between the two discoverers. The human note that is so frequently apparent in the book gives it special charm.

HENRY LEFFMANN.

DAS WERDEN DER WELTEN. Svante Arrhenius. Leipzig: Akademische Verlagsgesellschaft m. b. H. 8vo, 224 pages and index. Illustrated. Price, 5 marks.

When Arrhenius asks to be heard, the scientific world must "stop, look, and listen." The volume in hand is the German translation of his well-known work, an excellent product of the printer's art and an interesting product of the speculative spirit of a great scientist. The first chapters are devoted to terrestrial and celestial phenomena, the earth being especially studied in reference to the catastrophic changes, earthquakes and volcanic eruptions. Solar phenomena are then discussed, followed by studies of star clusters and nebulæ. A special chapter is given to pressure of light.

The most interesting chapter is the last, "On the Extension of Life in Space." In this the author sets forth his theory of the influence of light-pressure in driving minute spores to the different parts of space and the possibility of minute particles of cosmic dust serving as a sort of make-weight for these germs. He assumes a very abundant distribution and a comparatively small proportion of cases in which the germs light upon fertile places. One is reminded of the Parable of the Sower.

It is a disappointment that no suggestion is made in regard to the origin of life. The theory is offered only to account for the distribution of it, from some point of origin. A brief allusion is made to the suggestion that other elements of the carbon group may enter into protoplasmic constituents and give rise to protoplasm with special properties, but this speculation is rejected as very improbable.

Notice is made of some of the theories of spontaneous generation, but these also are not given any standing. It would have been very interesting to have Arrhenius's views on the relation of enzymes and colloids to vital phenomena, and some speculations as to the manner in which non-living matter might acquire vital character. Most of the so-called instances of spontaneous generation are unacceptable, because they claim the development of well-differentiated organisms. If spontaneous generation is now taking place, it is most likely to be the conversion of some complex mixture of nitrogenous bodies into a structureless and nearly quiescent mass. Long periods of evolution will probably be needed for the development of even a slightly differentiated organism.

HENRY LEFFMANN.

PUBLICATIONS RECEIVED.

Mechanical Laboratory Methods.—The testing of instruments and machines in the mechanical engineering laboratory and in practice, by Julian C. Smallwood, M. E., Associate Professor of Experimental Engineering, Syracuse University. 333 pages, illustrations, 12mo. New York, D. Van Nostrand Co., 1914. Price, in leather, $2.50.

Fabrikation und Eigenschaften der Metalldrahtlampen, von Dr. phil. N. L. Müller. 192 pages, illustrations, 8vo. Halle (Saale), Wilhelm Knapp. 1914. Price, in paper, 8.60 marks.

Théorie mathematique de l'Echelle musicale par Alphonse Vaucher. 67 pages, tables, 8vo. Paris, Gauthier-Villars, 1913. Price, in paper, 2.25 francs.

Canada Department of Mines, Mines Branch: Annual Report on the Mineral Production of Canada during the Calendar Year 1912 by John McLeish, B.A., Chief of the Division of Mineral Resources and Statistics. 339 pages, 8vo. Ottawa, Government Printing Bureau, 1914.

Providence City Engineer, Annual Report for the Year 1912. 84 pages, maps, tables, 8vo. Providence, R. I., City Printers, no date.

American Telephone and Telegraph Company, Annual Report of the Directors to the Stockholders for the Year Ending December 31, 1913. 68 pages, 8vo. New York, 1914.

Mellon Institute of Industrial Research and School of Specific Industries: Smoke Investigation, Bulletin No. 6. Papers on the Effect of Smoke on Building Materials. Edited by Raymond C. Benner, Ph.D. 58 pages, 8vo. Pittsburgh, Pa., University of Pittsburgh, 1913.

U. S. Department of Agriculture, Bulletin No. 14, Professional Paper, The Migratory Habit of Housefly Larvæ as Indicating a Favorable Remedial Measure. An Account of Progress, by Robert H. Hutchison, Scientific Assistant. 11 pages, 8vo. Washington, Government Printing Office, 1914.

United States Bureau of Mines: Report of the Director for the Fiscal Year ended June 30, 1913. 118 pages, map, 8vo. Bulletin 58, Fuel-briquetting Investigations, July, 1904, to July, 1912, by C. L. Wright. 277 pages, illustrations, 8vo. Bulletin 60, Hydraulic Mine Filling, Its Use in the Pennsylvania Anthracite Fields. A Preliminary Report, by Charles Enzian. 77 pages, illustrations, 8vo. Technical Paper 58, The Action of Acid Mine Water on the Insulation of Electric Conductors. A Preliminary Report, by H. H. Clark and L. C. Ilsley. 26 pages, illustrations, 8vo. Technical Paper 66, Mud-laden Fluid Applied to Well Drilling, by J. A. Pollard and A. G. Heggem. 21 pages, illustrations, 8vo. Washington, Government Printing Office, 1914.

Decomposition of Ytterbium into its Elements. C. AUER VON WELSBACH. (*Monatsh. Chem.*, xxxiv, 1713.)—By the fractionation of ytterbium the author isolated and purified the compounds of two constituent elements, cassiopeium, Cp, atomic weight = 175, and aldebaranium, Ad, atomic weight = 173. From the original 500 grammes of ytterbium oxide there were obtained about 48 grammes of cassiopeium oxide and over 200 grammes of aldebaranium oxide.

CURRENT TOPICS

Preparation of Metallic Tungsten. G. ERHARD. (*Metallurgie*, ix, 441.)—This paper discusses the various methods of obtaining metallic tungsten, and the conclusion is reached that the preparation of tungstic acid is the best intermediate stage. The purified sodium tungstate, obtained by fusion of the ore with 60 per cent. sodium carbonate, was treated with hydrochloric acid containing 6 per cent. of nitric acid, and the tungstic acid thoroughly washed to remove alkaline salts. After completely drying, 100 kilos. of tungstic acid were mixed with 14.1 kilos. of pure charcoal and 2 kilos. of rosin, and heated to 1400° C. in a crucible the lid of which was carefully luted. The agglomerated metal was then finely ground and elutriated in the usual way, yielding a product containing 96.5 per cent. of pure metal.

Melting-points of Commercial Brasses and Bronzes. ANON. (*Amer. Mach.*, xxxix, No. 24, 984.)—As the result of tests made under the direction of the United States Bureau of Mines, the following table of the melting-points of commercial brasses and bronzes has been summarized:

Alloy.	Approximate Composition.				Melting-point.	
	Copper.	Zinc.	Tin.	Lead.	C.°	F.°
Gun-metal	88	2	10	..	995	1825
Leaded gun-metal	85½	2	9½	3	980	1795
Red brass	85	5	5	5	970	1780
Low-grade red brass	82	10	3	5	980	1795
Leaded bronze	80	..	10	10	945	1735
Bronze with zinc	85	5	10	..	980	1795
Half-yellow, half-red	75	20	2	3	920	1690
Cast yellow brass	67	31	..	2	895	1645
Naval brass	61½	37	1½	..	855	1570
Manganese bronze	..	..	..	..	870	1600

The melting-point given is the "liquidus," or point where the alloy is completely molten. The tests are described in detail in Technical Paper No. 60.

Two New Types of Balance for Determination of Density. M. VON SCHWARZ. (*Centr. Min. Geol.*, 1913, 565.)—One end of the balance arm carries two pans, the lower immersed in water as usual, the other moving over a graduated scale. The weight in air and loss in water can then be read off directly in the same units, and the density calculated. Tables show very satisfactory results obtained with the two models. One model takes only 0.5 gramme of material, while the other model takes up to 100 grammes.

Uses of Tantalum. ANON. (*Amer. Mach.*, xxxix, No. 20, 998.)—In the *Chemiker Zeitung* some uses of tantalum are pointed out. Below 200° C. the metal is not attacked by air or oxygen, nor by acids, except concentrated hydrofluoric acid. It is not attacked by aqua regia, nor by aqueous solutions of alkalies, but is attacked by fused alkalies. It is a good substitute for platinum electrodes when used as cathodes. If used as an anode it rapidly oxidizes, which necessitates a thin electrolytic coat of platinum. It has a peculiar advantage for the electrolytic analysis of metals, as the deposit can be removed by solution in acids.

Influence of Different Metals on the Thermo-electric Properties of Iron-carbon Alloys. EUGÈNE DUPUY and A. PORTEVIN. (*Mon. Sci.*, iv, No. 865, 55.)—If, for each series of alloys with the same content of carbon, curves are constructed representing the variation of the mean thermo-electric power as a function of their content of added metal, it is concluded that nearly always tempering decreases the thermo-electric power, the differences between the results obtained for the alloys received and tempered being very small for those alloys which contain a considerable proportion of chromium or tungsten. The shape of the curve indicates that manganese, silicon, and aluminum produce solid solutions within the limits of the alloys which were examined. Metals such as chromium, tungsten, and molybdenum give a curve which at first takes a sharp drop, indicating a solid solution, then a rise, which seems to indicate the saturation of this solid solution.

Alloy of Cobalt and Tin. ANON. (*Amer. Mach.*, xxxix, No. 24, 978.)—The official chemist of the American Institute of Metals reports that an alloy of about 40 per cent. cobalt and 60 per cent. of tin is especially resistant to acids, but owing to its brittleness it has little commercial value. Experiments, however, show that admixtures of this alloy with other metals, such as copper, produce a series of alloys which can be turned, forged, and machined and still have a high degree of chemical resistance.

Metal Sledges at the South Pole. ANON. (*Metal Ind.*, xii, No. 1, 5.)—The daily press states that Sir Ernest Shackleton will use a new sledge in his next trip to the South Pole, which will be constructed entirely of metal. This metal is reported to be a steel composition, the make-up of which is a secret, but that the metal is extremely light and has great tensile strength. In view of these facts it is pretty safe to hazard a guess that the metal in question is not a steel composition but an aluminum alloy of the nature of magnalium or duralumin. It is claimed that by the use of this metal the weight of the sledge can be reduced 60 pounds, and this means a saving of 600 pounds weight on the ice, or 20 days' food for an ice party.

Application of Electricity and Radio-activity to Agriculture. T. THORNE BAKER. (*J. Roy. Soc. Arts,* lxii, 70.)—An account of the application of high-tension electric currents to the land by means of overhead wires for the purpose of increasing the yield of crops. It is stated that Lodge-Newman plants have been recently supplied to the Departments of Agriculture of the United States and of Egypt for experimental purposes: for 25 to 30 acres the capital outlay is $1000, but only $1500 for double the area. Experimental work has also been done on the effect of radio-activity, the waste material from the manufacture of radium being used, mixed with ordinary soil. Good results were obtained by mixing one part of radio-active material (2 milligrammes radium per ton) with ten of soil; with considerably larger quantities the yield was diminished and growth retarded. Some crops were benefited to a much greater degree than others: good results have been obtained with radishes and wheat, but much less marked improvement with cress; in the case of radishes the sugar content was markedly increased. It is stated that owing to the successful development of the processes of Kent-Smith and Rolfe and of Sommer comparatively poor residues from carnotite could be treated profitably for the extraction of radium, and that the supply of radium in the near future on a comparatively large scale was assured. The cost of the radio-active treatment of the soil would be about $2.50 to $3.75 per acre.

Hydrocarbons of Utah. C. BARDWELL, B. A. BERRYMAN, T. B. BRIGHTON and K. D. KUHRE. (*J. Ind. Eng. Chem.,* v, 973.)—The mineral hydrocarbons which occur most abundantly in Utah are gilsonite, tabbyite, wurtzilite, ozokerite, and rock asphaltum. Then follows a brief description of the chief deposits and a review of the literature. Some of the uses of the minerals are as follows: *Gilsonite* (of which 50,000 tons were produced in 1912): Used for the paving industry, electrical insulators, roofing materials, waterproofing pipes and aqueducts, preventing corrosion of the iron plates of ships' bottoms, coating wire fencing, sea-walls, poles, etc., lining tanks for chemicals, paints for smoke-stacks, lubricant for heavy machinery, rubber substitute, binder for briquettes. *Tabbyite:* Compositions for rubber floor mats, rubber paints and roofing materials, filler for rubber mixings for tires, etc. *Wurzilite* (of which 1000 tons per annum are produced): Varnishes, roofing compositions, etc. *Ozokerite:* Electrical insulators, altar candles, substitute for beeswax, ointments and the like, waterproofing mixtures, wax dolls, telephone receivers, phonograph records, polishes, electroplating, crayons, sealing wax. *Rock asphaltum:* Paving industry. The results of an experimental investigation of the mineral hydrocarbons mentioned are given, chiefly in tables, one of which shows the solubility of the different materials in various solvents, together with the corresponding figures for refined Trinidad pitch and Bermudez asphaltum.

A Wood that Never Rots. ANON. (*Sci. Amer. Suppl.*, lxxvi, No. 1978, 347.)—Engineers and others are annoyed by the rotting of railway sleepers, of piles, and of wood used to support galleries and in the building of ships, etc. Engineers, chemists, physicists, biologists, doctors, who for the construction of diverse apparatus, may need a wood possessing a maximum resistance to the causes of destruction, particularly humidity, are interested in this important question of the unputrescibility of wood. The ideal would be to find a wood able to resist putrefaction naturally. It appears from recent researches that the wood of the mangrove tree may be considered as absolutely unputrescible. Numerous samples of mangrove wood (*Rhizophora racemosa*) sent from French Guiana were, in 1909, placed at Collonges (Côte-d'Or) in a soaking pit in the depot of sleepers of the Paris-Lyons-Mediterranean Railway Company. These samples were surrounded with all the elements capable of producing the decomposition and rotting of the wood in the minimum of time. In spite of this the samples still remain in an excellent condition and show no signs of alteration. Why has the mangrove resisted decomposition and whence the particular and excellent qualities of this too little known wood? The grain of the mangrove is very close; hence it opposes a barrier to the invasion of water. The density of mangrove is about 110, that of oak is 70, and that of fir is 40. Moreover, mangrove wood has an amount of tannin quite sufficient to prevent the attack of insects and the multiplication of germs, damp, mould, and all the various micro-organisms which constitute the flora of the woods of different climates. The wood of the mangrove is marvellously resistant to flexion; its resistance is double that of oak, quadruple that of fir; nevertheless it is not at all brittle. To crushing, either at the end or across the fibres, it offers a resistance double that of oak and three times that of fir. It resists all attempts at twisting far better than either oak or fir, and is superior to them in suppleness. It is easily worked, and is as easily sawn as oak. It may, therefore, be concluded that mangrove wood merits employment on a large scale for numerous and varied purposes. It might be used for posts of electric lines on account of its unputrescibility, its resistance, and its suppleness. It is valuable for sleepers of narrow railways for its resistance to putrefaction and to crushing. It could be advantageously used for the special woodwork of mines. There is always good use for a wood that never rots.

Zirconium Hypophosphite, a Photo-sensitive Salt. O. HAUSER and H. HERZFELD. (*Z. Anorg. Chem.*, lxxxiv, 92.)—The hypophosphite is obtained by adding hypophosphorous acid to zirconium nitrate. The amorphous precipitate first formed redissolves in excess of the acid, and is precipitated by excess of alcohol as a colorless, crystalline precipitate, which, when dried over calcium chloride, has the composition $Zr(H_2PO_2)_4$. In direct sunlight the hypophosphite becomes deep violet. Microscopic examination of the colored crystals shows no evidence of decomposition.

The Tin-Plate Industry. (*Consular Report.*)—A report was recently presented to the British Tin-Plate Association on working conditions in Germany and Russia as compared with those in South Wales. The report was, in substance, as follows:

In Wales, 4 men per mill are employed—roller, doubler, furnace men, and behinder; in Germany, 5, the additional man being a furnace man's helper; in Russia, 7, the two additions being a behinder's helper and a bar dragger. In Wales the average output per 8 hours is 45 boxes of light plates 28 by 20 and 30 by 21 inches, as compared with only 42 in Germany, where there is a larger force per mill; in both countries the production sometimes reaches 60 to 70 boxes. The Russian mills have an average output of 95 to 100 boxes and an occasional output of 110 to 130 boxes. Their capacity is due to their large mill force and to the fact that the mills have three furnaces, one for heating the iron, and the other two in charge of the furnace man and his assistant, respectively. The German and Welsh mills have only two furnaces.

Radium Fixes on the Skeleton. ANON. (*Sci. Amer. Sup.*, lxxvi, No. 1978, 343.)—M. Domenici and M. and Mme. Laborde have injected into animals radium salts in a soluble state, and have searched the place of fixation. Fragments of bone tissue have appeared constantly radio-active during the experiments; and the experimenters have tried to make a precise determination of the quantities of radium fixed by the skeleton, the muscles, the viscera, and the skin respectively. A rabbit was killed thirty-three days after an intravenous injection of 0.06 milligramme of pure radium associated with an equal quantity of radium bromide. The skeleton, the muscles, the viscera, and the skin were then burned separately. The ashes showed that the radium was fixed on the skeleton rather than on the other parts of the organism, where it is found in only very feeble quantities. In their communication to the Biological Society, MM. Domenici and Laborde conclude that it is very probable that the ingestion of radium salts would have the same effect. Considering the well-known affinity of the skeleton for calcium and strontium salts introduced into the organism, it is quite probable that radium salts would also be fixed on the skeleton.

Electrical Properties of Copper-tin Alloys. R. LEDOUX. (*Comptes Rend.*, clv, 35.)—The author determines and plots curves to represent: (1) the electrical resistance, (2) the temperature coefficient of resistance between 0° and 100° C., (3) the thermo-electric power against lead, and (4) the temperature coefficient of the thermo-electric power, in each case, for alloys with varying percentages of copper and tin. Practically all the measurements indicate the compound Cu_3Sn, while several of the curves indicate the existence of a compound with the formula Cu_4Sn.

Pressure of Light Measured by Use of Thin Foil. G. D. WEST. (*Phys. Soc. Proc.*, xxv, 324.)—The pressure of the radiation emitted by a carbon filament lamp at a distance of a few centimetres is sufficient to cause a microscopically measurable deflection of the end of a suspended strip of gold or aluminum foil, and by this means the radiation pressure can be calculated if the weight of the strip is known. The results agree to within about 10 per cent. with the energy density of radiation as measured by the initial rise of temperature of a copper plate exposed to the radiation. The best results are obtained by working in an atmosphere of hydrogen, at 1 cm. to 2 cm. pressure, but good results are obtained with hydrogen at atmospheric pressure. Air at 1 cm. to 2 cm. pressure also gives good results. The method involves no laborious adjustments, and the apparatus is not seriously affected by vibration.

A New Element in the Atmosphere. F. W. ASTON. (*Eng.*, xcvi, 423.)—In his studies on the positive rays, J. J. Thomson obtained indications of the presence in the air of a body of atomic weight about 22 and giving a line next to neon, atomic weight 20. On continuing this work the conclusion is reached that atmospheric neon is a mixture of two gases which are identical in all their properties except their atomic weights, which are respectively 19.9 and 22.1. By 3000 fractionations of the gas, or, better, by using the diffusion method in conjunction with a new quartz-disc density balance in which 0.5 c.c. of the gas is weighed against oxygen, it is found that ordinary neon contains about 12.5 per cent. of the heavier gas, which does not appear to be a compound. The spectra of the two gases are apparently identical.

Neutralization of Chromic Acid. L. MARGAILLAN. (*Comptes Rendus*, clvii, 994.)—The progressive neutralization of chromic acid by sodium hydroxide was followed by the electrometer method, using an electrode of platinum saturated with hydrogen. The e.m.f. curve was interrupted by two almost vertical portions (instead of one, as with sulphuric acid), corresponding respectively to the addition of one and of two equivalents of alkali.

Observations of the Afterglow. B. THIEME. (*Deutsch. phys. Gesell. Verh.*, xv, 16, 794.)—A preliminary communication describes briefly several new observations on the afterglow produced in the gas of a low-voltage carbon-filament lamp after a discharge has been passed, by placing it in an alternating field of high frequency (a Tesla field). The conclusion is that the afterglow is a periodic discharge occurring about 30 or 40 times per second, the period becoming smaller the longer the duration of the effect. Experiments on the discharge which occurs when the bulb of the lamp is electrified by friction are also described, with the conclusion again that the discharge is periodic. Further experiments are being made which will be described in a later communication.

Soft Artificial, Frit or French Porcelain. A. GRANGER. (*Bull. Soc. d'Encour.*, cxx, 195.)—A history of the origin and development of the various forms of porcelain, especially those of France and of Sèvres.

Modern soft porcelain dates from 1879, when Lauth found by analysis that the composition of the ware varied considerably with the firing temperature, owing to the volatilization of the alkalies. It was decided to use a more acid frit and Stas glass, which has the composition $SiO_2$77, CaO10.3, K_2O7.7, Na_2O5.05 per cent., was employed, while the marl was replaced by a mixture of chalk and Dreux clay. The figures for the body mixing were: Sand, 49; Stas glass, 27.5; chalk, 16.66; Dreux clay, 6.86. The chemical composition was: SiO_2, 80.31; Al_2O_3, 2.62; CaO, 13.27; R_2O, 3.8; which meant that nearly 5 per cent. more silica was introduced at the expense of the lime and alkalies. More recent mixings, used for ware exhibited at the 1900 Exposition are: Sand, 33; Stas glass, 46; chalk, 14; Dreux clay, 7; with a glaze formula: 0.46 Na_2O, 0.54 PbO, 2.5 SiO_2. The ware is fired at cone 4 instead of at cone 7, like Lauth's mixing. Still more recently, kaolin has been substituted for Dreux clay, but the composition is not published. This new ware is called soft kaolin porcelain.

Preservation of Hydrogen Peroxide. A. M. CLOVER. (*Amer. J. Pharm.*, lxxxv, 538.)—The addition of 0.05 per cent. of acetanilide to hydrogen peroxide solution increases its stability to such an extent that only about 2.7 per cent. is decomposed in five months. The presence of mineral acids and of salts of the alkalies and alkaline earths has no influence on the stability of the peroxide solution; while traces of copper and iron increase the rate of decomposition.

Canadian Asbestos. ANON. (*J. Roy. Soc. Arts*, lxii, 36.)—The province of Quebec contains the principal asbestos-producing areas of Canada. The present workable deposits are scattered through the great serpentine range which strikes through the townships of Broughton, Thetford, and Coleraine. The total length of the belt is 23 miles, with a width of 100 feet in the extreme easterly part, increasing to 6000 feet in the Mock Lake area. The principal deposits are at Thetford, Black Lake, Danville, and East Broughton; the first two are the most important. The mineral occurs in a series of narrow and irregular veins, sometimes, though rarely, reaching a width of six inches. Large mills are now in operation in which the rock is broken and crushed and the fibrous asbestos is taken up from screens by suction fans, and blown into settling chambers. At present the annual production is over 100,000 tons, valued at upwards of $3,000,000. It includes a large variety of grades, from the long-fibred crude asbestos, valued at $300 a ton, down to the shortest mill fibre, valued at only $2 or $3 per ton, and "asbestic sand," used for wall plaster, and valued at from 75 cents to $1.50 per ton.

Radiotelegraphy between Nauen and Long Island. ANON. (*Eng.*, xcvi, No. 2484, 206.)—According to the *Telefunken Zeitung*, an exchange of messages has taken place since the beginning of 1913 between the Telefunken station at Nauen, where the 100-metre tower, which was blown down by the wind, has been brought up to its projected height of 200 metres, and Sayville, on Long Island. This station belongs to the Atlantic Communication Company. The distance is 6500 kilometres, just double that between the west of Ireland and Cape Breton Island, where Marconi stations have been working for some years. By using high-frequency generators Nauen is said to have made successful radiotelephone experiments with Vienna and other places up to 700 kilometres distant. Radiotelegraphic signals over exceptionally long ranges were overheard at Awanui, in New Zealand, which travelled 7800 kilometres from steamers travelling between Honolulu and Yokohama (Marconi apparatus) and at Pennant Hill, in Australia, in which case the signals came from a cargo steamer 6700 kilometres distant (Telefunken apparatus).

Consumption of Aluminum. ANON. (*Metal Ind.*, xii, No. 1, 3.)—More than 65,000,000 pounds of aluminum were consumed in various industries in the United States in the year 1913. This makes a new high record for aluminum consumption.

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